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Academy of Denture Prosthetics Meeting, Minneapolis, Minn., May 7 to 12, 1961.
Southeastern Academy of Prosthodontics Meeting, Miami Beach, Fla., May 18 to 21, 1961.

THE JOURNAL OF PROSTHETIC DENTISTRY

VOLUME 11 MARCH-APRIL, 1961 NUMBER 2

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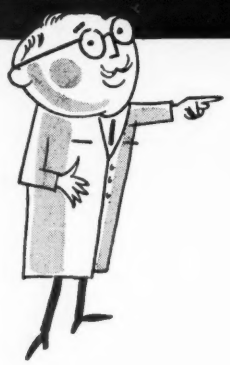

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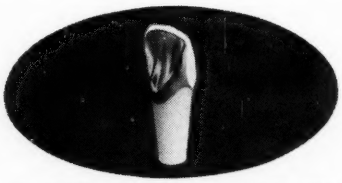

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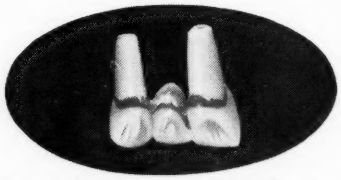

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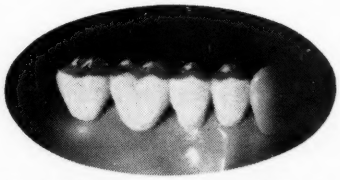

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Hiroyasu Hosoda, D.D.S., D.M.Sc., and Takao Fusayama, D.D.S., D.M.Sc., Tokyo Medical and Dental University, Tokyo, Japan **318**

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how characterized should a characterized tooth be?

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THROUGH THE EYES OF THE EDITOR

Carl T. Ostrem discusses the relining of dentures as a part of the essential service to denture patients and describes his relining technique. The impressions are made in impression wax, and the jaw relations and occlusion are established on the articulator by means of interocclusal records. The relining of dentures is not generally looked upon (by patients) as a difficult procedure. In reality, it is one of the most difficult operations in dentistry. Almost all of the chairside decisions necessary for the construction of new dentures must be made while the impressions are being formed. The remounting procedure suggested allows certain corrections to be made after the impressions are completed.

Robert Rothman discusses speech sounds and the effects that dentures have upon the production of these sounds. He suggests the possible causes of various speech defects which may occur when a patient wears dentures. When the mechanism for producing speech sounds is understood, the diagnosis of the cause of difficulty becomes simple.

Arne G. Lauritzen and George H. Bodner report their tests of the accuracy of location of the hinge axis points by arbitrary means. Their results show a higher percentage of error in arbitrary axis location than some others have reported. These errors should be avoided, or techniques for making corrections in the resulting occlusal errors should be used.

R. Lyndsay Campbell made a survey of dental schools to determine whether relief is used in upper dentures and the method for providing it. He found considerable variation exists in education regarding relief in the various dental schools. This is an indication of the need for further study of the gross and microscopic structures under dentures. The use of arbitrary shapes and amounts of relief does not appear to be justified.

Arthur N. Bahn and Roger C. Michalsen report their tests of the effectiveness of adding certain bacteriostatic agents to denture-base materials. The results indicate that further laboratory and clinical tests should be made to determine the value of using the additives. The limited time during which they are effective seems to be a major problem.

Joseph S. Landa continues his discussion of the diagnosis and treatment of patients who have trouble wearing dentures. The problems discussed in this article are among the most perplexing to be faced by dentists. A patient annoyed by excess saliva, a dry mouth, or burning sensations under dentures can experience these difficulties as a result of the dentures or because of systemic or psychologic conditions. An accurate differential diagnosis is essential, and suggestions are made regarding diagnosis and treatment.

Benjamin W. Dunn describes his procedures for designing removable partial dentures on diagnostic casts. These casts are accurately made, mounted on an articulator, and then surveyed. This should avoid many problems in the development of occlusion in the restora-

tions. The denture design is outlined in different colored pencils so the technician has positive instructions regarding the total design and all of its components.

Magne Hekneby discusses the movements of denture bases while under the stress of masticatory forces and describes his stress-breaking device, which permits the bases to move without placing stress on the abutment teeth. The amount of movement can be varied according to the resiliency of the soft tissues. The device is ingenious and should be valuable where it is indicated.

Harry R. Skurnik and Berl Mendel discuss the use and construction of periodontal prostheses. Their technique involves the use of rubber-base impression materials. The complete impressions are essential because they permit the development of a harmonious occlusion, which is the objective. These appliances should be used only as adjuncts to other types of treatment of periodontal disease.

Berton M. Rudin discusses the choice of abutment restorations for fixed prostheses and suggests pinledge crowns as conservative retainers. He lists the advantages and disadvantages of pinledge crowns and describes his technique for making them. These restorations can be effective if they are carefully constructed and if they are modified to meet the requirements of abutment retainers.

Milton Hausman describes his techniques for making transitional crowns of acrylic resin or metal and discusses their uses. When several teeth are being restored at one time, the restorations must be accurately related to each other in the same arch and to the opposing occlusion. Transitional copings facilitate this operation as well as serving other functions.

John H. Mosteller discusses the restoration of teeth with silver amalgam. He points out the tremendous improvements in this material and in the techniques for its use. These changes have come about gradually and without fanfare. Nevertheless, it is possible to build better amalgam restorations now than has been possible in the past. It is important that the new information be applied in order to obtain the best results.

Robert Going and Maury Massler report their tests of the effectiveness of various cement bases and cavity liners. They used radioisotopes to detect the leakage around amalgam fillings and penetration into the dentine and pulp. This new experimental method provides a means for comparison that has not been possible previously. Even though the radioactive isotopes may not travel the same as oral fluids, the comparisons they provide are valuable. The results indicate a great variation of the resistance of the various liners and bases to penetration by the radioisotopes.

Alfred Schuchard and Charles Watkins measured the temperature rise in dental pulp with various rotational speeds of cutting instruments used with different coolants. Their results indicate that thermal damage to the pulp does not result if the appropriate coolant is used. They suggest, however, that other tests should be made in order to evaluate the effects of high rotational speeds because factors other than heat may be involved.

Hiroyasu Hosoda and Takao Fusayama report their studies of the distortion that occurs in irreversible hydrocolloid and mercaptan rubber-base impressions. On the basis of their tests, they recommend fixing irreversible hydrocolloid impressions for 30 seconds before the casts are poured. They showed that several factors influence the accuracy of casts differently for the two classes of materials. These factors should be considered in the clinical techniques in which these materials are used.

John N. Pettrow discusses the various factors which determine the success or failure of porcelain jacket crowns. All of the operations must be carried out with meticulous accuracy in order to avoid failures. He points out the most important causes of failures of these restorations and certain modifications of technique which will improve the chances to avoid trouble. He bases his suggestions on a study of many defective and fractured crowns.

Clifton Dean Adams discusses diet and nutrition and their relation to some dental problems. He points out some of the oral symptoms of nutritional deficiencies and suggests dietary modifications to improve the health of the patient and his reactions to prosthodontic treatment. Nutritional deficiencies and imbalances increase with the age of the patient. When they are detected, changes in diet should be made under joint medical and dental care. Otherwise, patients may become victims of fads.

George A. Graham describes the construction of a postsurgical obturator. Self-curing acrylic resin was used, and the restoration was made 5 days after surgical operation. This points up the fact that the available pros-

thodontic materials and methods allow dentists to render valuable service to the morale and well-being of postsurgical patients at a time when they need it desperately.

Sigurd P. Ramfjord reports his studies of temporomandibular joint and muscle pain by means of clinical evaluation of the occlusion and electromyographic analysis. The results indicate that the removal of unharmonious occlusal contacts eliminated the symptoms. The most common "trigger" for the symptoms was a centric occusion that did not coincide with centric relation, and the disharmony was more likely to cause trouble in swallowing than in mastication. It is interesting to note that neither distal displacement of the condyles nor overclosure of the mandible was found to cause the symptoms. It is possible that some concept which was more or less accepted in the past should be reviewed in the light of this information.

John W. Knutson reports on current research in prosthodontics and discusses its importance for the future. Many problems relating to prosthodontics are bing studied, but he suggests that much more research is needed. The challenges he lists deserve the attention of all dentists, and with the present population and social trends, the opportunities are unlimited.

Warren O. Nelson discusses current research in the regulation of fertility. He points out the rapidly increasing population of the earth and the fact that if the increase continues long enough there will not be enough food to sustain the people. While this situation will not become critical in our lifetime, it is one in which we all have a responsibility to future generations.

Charles M. Enright discusses dentist-laboratory relations on the basis of the responsibilities of both the dentist and the laboratories. Since the quality of prosthetic appliances depends upon a coordinated technique, it is imperative that a mutual understanding exist between the dentist and the laboratory technician. The plan to be followed must be directed by the dentist so that the laboratory technician can complement the work done by the dentist. The dentist must provide adequate written instructions, and the instructions must be followed if the best results are to be attained.

—Carl O. Boucher

COMPLETE DENTURES

RELINING COMPLETE DENTURES

CARL T. OSTREM, D.D.S.
Des Moines, Iowa

RELINING COMPLETE DENTURES is an obligation of dentists and a real service to denture patients. However, relining is not a cure-all. Improperly constructed and ill-fitting dentures with an unesthetic appearance should be remade. Relining can be described as a "rehabilitation of dentures."

PRE-EXTRACTION RECORDS

The amount of change of ridges under dentures is variable, depending on many factors such as occlusion, health, quality of bone, etc. Therefore, facial measurements and study casts made prior to extractions should be used as guides in relining procedures.

A Sorenson gauge is used to measure the distance from the bridge of the nose to the chin (Fig. 1). These two landmarks are constant. Therefore, if the original dentures were constructed to this measurement, it can be used as a guide in relining.

The S. S. White gauge can be used to measure the distance from the septum of the nose to the incisal edge of upper anterior teeth. Almost 75 per cent of natural teeth will measure 25 mm. from the septum of the nose to the incisal edge with this gauge. Natural teeth can vary from 23 to 27 mm. and still have pleasing appearance. Any distance less than 23 mm. or more than 27 mm. usually leaves something to be desired in the esthetics of the natural teeth. This is an aid in the construction or relining of dentures when no original records are available.

A RELINING ESSENTIAL

The patient must leave the dentures out of the mouth for a minimum of 48 hours before relining procedures are started. Sometimes, when the health of the tissues is poor, it is necessary to increase this time. I have yet to find a patient who will not cooperate when the reason is properly explained.

Read before the Academy of Denture Prosthetics, Louisville, Ky.

LOWER DENTURE RELINING TECHNIQUE

At the first appointment, the dentures are inserted momentarily, and the patient is asked to place the tip of the tongue as far back on the palate as possible and then close the mouth. The closure will be with the mandible in centric relation. The position of the tip of the tongue on the palate is noted, and a small piece of stick modeling compound is placed on the upper denture at that point. The compound gives the patient something definite to touch with the tongue when centric relation closures are desired.

LOWER DENTURE-BASE PREPARATION

Indelible pencil marks (2 to 3 mm. in diameter) are placed on both sides of the lower denture on the buccal and lingual slope of the alveolar groove in the first bicuspid and second molar regions. Then, an area of similar size is marked on the buccal side of the lingual flanges. These marks are slightly away from the

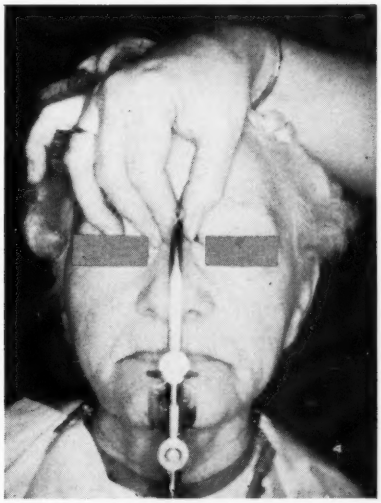

Fig. 1.—The change in the vertical dimension of occlusion is indicated by a change in measurement on a Sorenson gauge.

border of the retromylohyoid eminence at the distal end of the flange (Fig. 2). Thus, five areas are selected on either side of the denture for guiding it into position. Acrylic resin is removed from the remaining part of the tissue surface of the denture to a depth of 1 to 2 mm. The entire border of the denture is reduced from 1 to 2 mm., and the buccal and labial notches are deepened.

PRELIMINARY IMPRESSION

A roll of brown stick modeling compound is placed on the buccal, labial, and lingual borders but *not* on the retromylohyoid eminence (Fig. 3). The upper denture is covered with a heavy coating of denture powder and placed in the

mouth. The modeling compound on the lower denture is slowly heated with an alcohol torch, allowing the heat to soak in rather than to apply the flame constantly and overheat the surface. The compound is tempered by dipping the denture in water at 115° F. Then it is inserted in the mouth. The patient is instructed to reach for the piece of compound on the palate of the upper denture and to close with a mild pressure. The lower denture is chilled in the mouth, removed, and placed in ice water (Fig. 4).

Fig. 2.

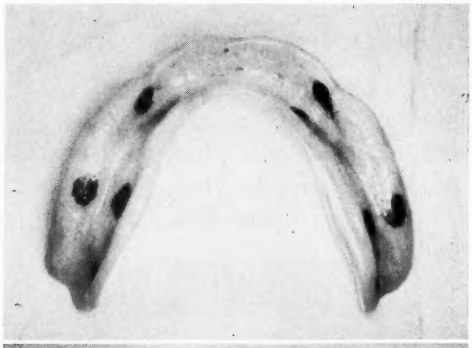

Fig. 3.

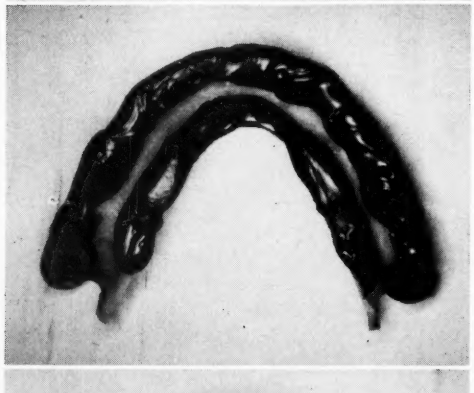

Fig. 4.

Fig. 2.—The areas marked are not relieved and serve to reposition the denture while the impression is being made. The unmarked surface is ground away.

Fig. 3.—Excess modeling compound is placed on the borders of the denture except at the distal end of the lingual flanges.

Fig. 4.—The modeling compound covers the tissue surface of the lower denture base.

Fig. 5.

Fig. 6.

Fig. 5.—The lips are pursed forward to mold the modeling compound on the borders of the dentures.
Fig. 6.—The lips are pulled posteriorly to mold the borders.

BORDER DEVELOPMENT

The modeling compound on the buccal border on one side is heated as far forward as the cuspid region. The seating surface is not heated. The denture is inserted, and the patient is directed to reach for the compound mound on the palate of the upper denture with the tip of the tongue and to close the mouth. Then, the patient is directed to purse the lips forward and pull them backward (Figs. 5 and 6). This action rolls the excess modeling compound over the buccal border. The same procedure is repeated on alternate sides until no more modeling compound rolls over the borders. The excess modeling compound can be trimmed away with a sharp knife. Then the labial border is molded in a similar manner, and the buccal and labial frenula are manipulated slightly to give them a little additional freedom.

Fig. 7.

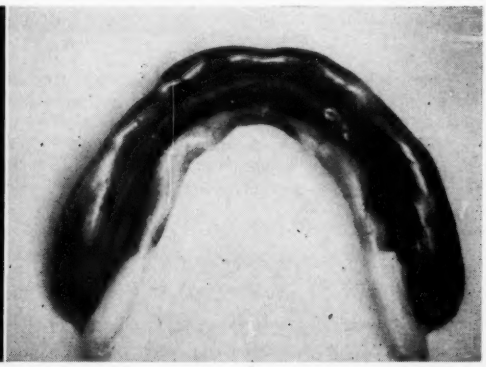

Fig. 8.

Fig. 7.—The modeling compound impression is completed.
Fig. 8.—The impression is completed by adding wax to eliminate defects in the modeling compound impression.

Fig. 9.

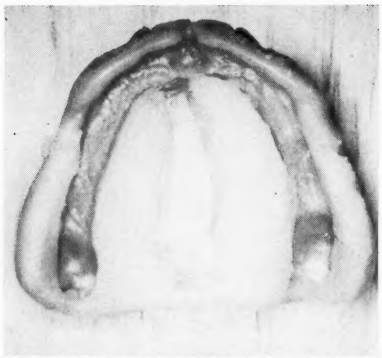

Fig. 10.

Fig. 11.

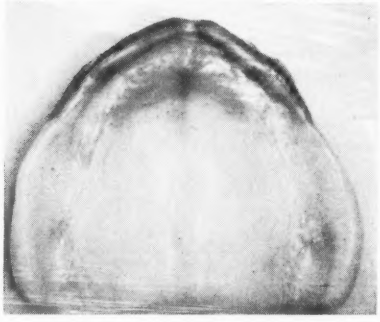

Fig. 9.—Paraffin wax is placed on the borders and the palate of the upper denture. Note that no wax has been placed on the relief area, in the alveolar groove, or in the anterior part of the dentures.

Fig. 10.—The wax has blended smoothly across the ridge and into the relief area.

Fig. 11.—The upper wax relining impression has been completed by the addition of low-fusing impression wax over the anterior part of the denture.

The modeling compound on the lingual border is heated in the same manner, and the patient is directed to close the mouth and swallow. This procedure is repeated until the compound fails to roll over the border. Then, one side of the lingual surface is heated. The heat is kept away from the area of the lingual frenum. The patient is directed to put the tongue in the cheek on the side opposite the softened border.

White stick modeling compound is molded over the distal end of the lingual flange (the retromylohyoid eminence) on one side and chilled in ice water.

The compound on the buccal side of the distal end of the lingual flange is heated and tempered, and the denture is inserted in the mouth. The patient is instructed to close the mouth in centric relation and swallow. Next, the distal border of the retromylohyoid eminence is heated, and the patient is directed to extend the tongue outside the opposite corner of the mouth with a great deal of force. Then, the lingual border is heated from the lower part of the distal border forward to the second bicuspid region, and the patient is directed to place the tongue into the opposite cheek with great force. The same procedures are repeated on the

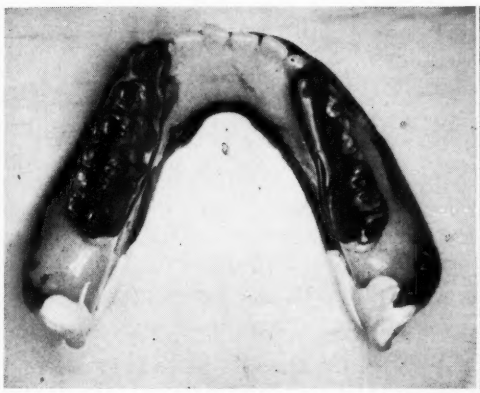

Fig. 12.

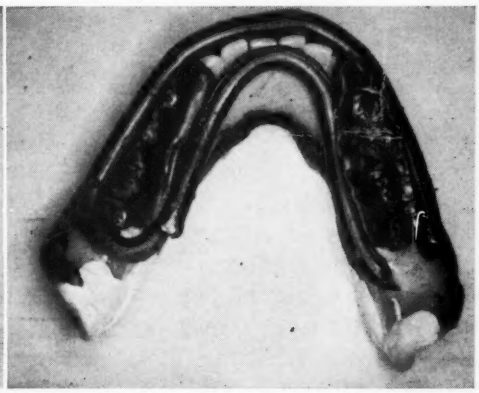

Fig. 13.

Fig. 12.—An interocclusal wax centric relation record is made and left on the lower denture.

Fig. 13.—The wax interocclusal record is protected from distortion during the pouring of the cast.

opposite side of the denture. Finally, all lingual borders are heated slightly, the denture is inserted very carefully, and the patient is directed to close the mouth in centric relation and swallow several times (Fig. 7).

FINAL LOWER RELINING IMPRESSION

The guiding areas on the slopes of the alveolar groove (Fig. 2) are removed. The guiding areas on the retromylohyoid eminences are not disturbed. For final detail, a low-fusing wax* is used. (A low-fusing wax can be made by combining 60 per cent paraffin, 20 per cent spermaceti, and 20 per cent ceresin in a double boiler.) The wax is painted carefully in the areas where the guiding surfaces were removed, on any other defective surfaces in the modeling compound, and lightly on all borders with a camel's hair brush. The denture is inserted in the mouth and allowed to remain there while the relining procedures are carried out on the upper denture (Fig. 8).

*University of Iowa Wax.

Fig. 14.—Wax stops are used to reposition the lower denture on the cast.

UPPER DENTURE RELINING TECHNIQUE

The denture powder is removed from the upper denture. Pure paraffin is then heated in a small egg steamer. The wax is painted on the tissue surface of the palate and on the buccal borders as far forward as the first curvature of the ridge. This is usually in the region of the first or second bicuspids. The part of the denture covering the crest of the ridges and the center of the palate are left open (Fig. 9). The denture is then dipped in tempering water at 115° F. and gently seated to place. The procedure is repeated until the occlusion is approximately correct and the wax has flowed toward the crest of the ridge and toward the center of the palate. If the line of union (where the wax comes together) is irregular, a sharp lance is used to even the wax until a smooth junction is obtained (Fig. 10). This procedure records the shape of the posterior parts of the ridge without moving the denture forward.

Low-fusing wax is painted on the inside of the labial flange and a slight amount is added just lingual to the crest of the anterior part of the ridge. The part of

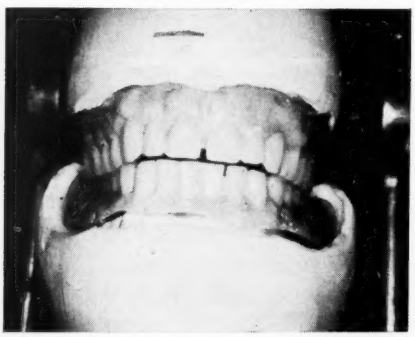

Fig. 15.—The lower denture is positioned in relation to the upper denture and guided by the centric occlusion.

the denture covered with the paraffin is dipped in ice water, and the labial portion is quickly dipped in tempering water at 115° F. The denture is inserted, and the patient is instructed to close the mouth in centric relation. Any defects or lack of wax in the anterior region are corrected, and the same procedure is repeated (Fig. 11). The patient is allowed to sit with both dentures in the mouth for 30 minutes without applying any pressure.

JAW RELATION RECORDS

A protrusive record is made in a triple thickness of beeswax placed on the lower posterior teeth and uniformly heated in warm water. This record is removed and is used to adjust the condylar guidances when the casts are mounted on the articulator. The lower denture is chilled and removed, and the protrusive record is removed and laid aside.

Wax* is placed on the posterior teeth from the first bicuspid to the middle of the second molar. The patient is instructed to close the teeth lightly in centric relation into the wax. The patient *must not* close the teeth through the wax at any point. The Sorenson profile gauge is used while the centric relation record is made so that a vertical relation is established which is the same as that with the original dentures when they were new. The S. S. White gauge is used to make sure the distance from the septum of the nose to the incisal edge of the upper central incisor is restored. The wax record is then chilled and the dentures are removed (Fig. 12).

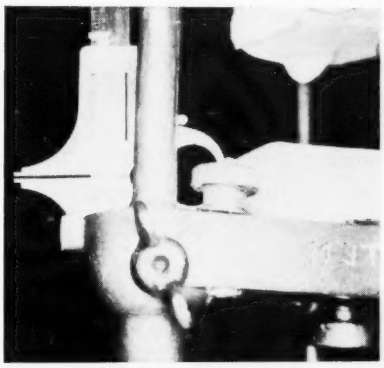

Fig. 16.—The articulator posts are raised to create an occlusal pivot. The wing nut locks the post in its raised position.

MOUNTING THE CASTS

The wax centric relation record on the lower denture is protected with strip boxing wax (Fig. 13), the upper and lower impressions are boxed, and

*Wax Square Rope, Modern Materials Mfg. Co., St. Louis, Mo.

casts are poured in artificial stone. The casts are notched for remounting, or remounting plates can be used. The face-bow can be used to mount the upper cast, and the lower dentures are placed together in the wax record. The casts are mounted on a modified Hanau articulator. The teeth are cleaned, and the condylar guidances are set by means of the protrusive wax record.

REPOSITIONING THE LOWER DENTURE

After being mounted on the articulator, the wax on the upper denture is left intact so the upper denture can be replaced on the cast in exactly the same position after being removed. The modeling compound is removed from the lower denture, and pink baseplate wax is placed in the first molar regions and on the anterior part of the ridge (Fig. 14). The wax is heated slightly, and the lower denture is repositioned to the upper denture with the use of the occlusion of the teeth as a guide (Fig. 15). The articulator is closed in centric position with the pin set as it was when the casts were first mounted. The lower denture is then waxed up and a try-in is made, if desired.

OCCLUSAL PIVOT

The modified articulator I use has wing nuts on the back of the posts and two setscrews on the bottom (Fig. 16). The setscrews controlling the posts are loosened, and the posts are raised 1 to 1.5 mm. The dentures are reoccluded to this position by changing the position of the upper denture on its cast. This accomplishes the "pivot" action as described by Sears.[1]

LABORATORY PROCEDURES

The casts are removed from the articulator. The palate is cut out of the upper denture to allow for proper palatal thickness, and the buccal and labial borders are shortened slightly. Relief areas are covered with the desired thickness of metal, and the posterior palatal seal is cut into the upper cast. The wax over the ridge of the upper denture is left intact while cutting out the palate so that the seating of the upper denture is not changed. The final waxing is completed, and the dentures are flasked and trial packed.

Hard Klinging Liner Plastic* is added for the final lining. Moisture adheres to this material. The dentures are trial packed once more, the cellophane is left in, and the flasks are closed. The resin is cured at 169° F. for 1½ hours and then boiled for 2 hours. Then, the flasks are bench cooled.

The dentures are removed from the flask without removing them from the casts, and they are placed back on the articulator. The occlusion is corrected by grinding and milling, if needed.

The dentures are removed from the casts, polished, and placed in the patient's mouth. In 24 hours, the dentures are remounted on the same articulator from a new interocclusal wax record, and the occlusion is corrected again if necessary.

*Ad-hez, Bosworth Mfg. Co., Chicago, Ill.

SUMMARY

A relining technique for complete dentures has been described. Wax impressions are made in the denture bases with the use of centric relation as a guide for positioning the dentures. The correct vertical dimension of occlusion is reestablished while a new interocclusal centric relation record is made. Centric occlusion is preserved by correctly positioning the lower denture to the upper denture after the casts have been mounted on the articulator. Hard Klinging Liner Plastic is used as the final relining material.

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1. Sears, V. H.: Occlusal Pivots, J. Pros. Den. **6**:332-338, 1956.

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PHONETIC CONSIDERATIONS IN DENTURE PROSTHESIS

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SPEECH IS ESSENTIAL to human activity. Therefore, phonetics must be considered with mechanics and esthetics as the cardinal factors contributing to the success of the dental prosthesis.[1-3]

In order to deal with the problem of phonetics, the general mechanism of speech production and the specific mechanics of the production of sound units of dental interest must be understood. A working knowledge of this information enables the dentist to fabricate a denture with which speech is clearer,[4] and it gives him a series of phonetic tests useful in complete denture registrations.

MECHANISM OF SPEECH PRODUCTION

Air from the larynx is divided into two streams by the velum. The upper air stream is used in speech for the sounds *n, m, ng* and for resonance. All other sounds are produced with the lower air stream as it strikes the palate and is altered by the oral structures.

Thus, normal speech depends upon the proper functioning of five essential mechanisms: (1) the *motor,* consisting of the lungs and associated musculature which supply the breath (air), (2) the *vibrator,* consisting of the vocal cords which give pitch to the tone, (3) the *resonator,* consisting of oral, nasal, and pharyngeal cavities and paranasal sinuses which create overtones peculiar to each individual, (4) the *enunciators* or *articulators,* consisting of the lips, tongue, soft palate, hard palate, and teeth, which form musculoskeletal valves to obstruct the passage of air, breaking up the tones and producing the individual speech sounds, and (5) the *initiator,* consisting of the motor speech area of the brain and the nerve pathways which convey the motor speech impulses to the speech organs. The initiator is of importance in the neurotic patient or the patient with a nervous disorder who has apparent difficulty even though the denture is phonetically correct. Such a patient requires careful instruction and practice in proper enunciation. Also, normal aural acuity is an essential factor in learning to speak well with dentures.[5,6]

The primary concern in phonetics is with the changes in the stream of air as it passes through the oral cavity.[1] Therefore, the enunciators or articulators are of greatest interest to us. Of these, the tongue plays a major role. The tongue is the principal articulator of the consonants and changes position and shape for the pronunciation of each of the vowels. In pronouncing each consonant, the tongue contacts a specific part of the teeth, alveolar ridge, or hard palate. These structures are covered or replaced by the denture, and the dentist must know where the tongue contacts them so that they may be appropriately restored in the prosthesis.[3]

CONSONANTS

The consonant sounds are most important from the dental point of view. They may be classified[1] according to the anatomic parts involved in their formation: (1) the palatolingual sounds, formed by tongue and hard or soft palate, (2) the linguodental sounds, formed by the tongue and teeth, (3) the labiodental sounds, formed by the lips and teeth, and (4) the bilabial sounds, formed by the lips.

PALATOLINGUAL SOUNDS FORMED BY TONGUE AND HARD PALATE

S.—The sound *s,* as in *s*ixty-*s*ix, is created by the hiss of air as it escapes from the median groove of the tongue when the tongue is just behind the upper incisor teeth.[2] The sides of the tongue are in contact with the upper posterior teeth and alveolar ridges,[7] and this contact may extend as far forward as the region of the lateral incisors.[3]

The essential factor in the production of a correct *s* is the proper grooving of the tongue. As the depth of this groove is decreased, *s* is softened toward *sh,* and as the groove is further decreased, toward *th* as a lisp. Excessive thickness of the denture base in the anterior part of the palate is often the cause of lisping. Where the groove of the tongue is too deep, the patient may whistle when making the sound *s.* Lisping and whistling are opposite phenomena. If the patient whistles, the depth of the groove of the tongue should be decreased by thickening the denture base in the appropriate area.

The location of the groove in the tongue does not always correspond with the location of the median raphe of the palate. Therefore, if the patient experiences difficulties with the sound *s,* the exact position of the groove in the tongue should be determined with relation to the palate. When this part of the palate has been located, the dentist can deepen the groove in the denture base to correct lisping or make the groove more shallow to eliminate whistling.

The exact position of the groove in the tongue in relation to the palate can be determined by making a palatogram with the upper trial denture. The palatogram is made by drying the palatal surface of the upper trial denture and dusting it with talc. Then the denture is inserted in the mouth, and the patient pronounces the desired sibilant sound. Upon removal and inspection of the denture, one will see where the powder has been wiped away by contact with the tongue. Corrections can be made according to the palatogram. A comparison of the palatograms of the sounds *s, sh,* and *th* shows how the depth of the groove in the tongue is the critical factor in the differentiation between the three (Fig. 1).

The position of the anterior teeth also is involved in the production of the sound *s.* As the lower incisors are set further back, *s* is softened toward the lisp because the tongue is crowded posteriorly, causing the groove in the tongue to become more shallow. Conversely, when the lower incisors are set too far labially, the *s* will whistle since the tongue will be overextended anteriorly and cause the groove in the tongue to deepen.

The sound *s* may be distorted to a slushy *sh.* This results from leakage of air at the lateral borders of the tongue when the tongue is not sufficiently confined in the bicuspid region. This phenomenon, known as stigmatismus lateralis,[2] may be

corrected by creating palatal eminences bilaterally on the denture base corresponding to the naturally occurring prominences of the alveolar ridges in the bicuspid-molar regions.[3]

Finally, the proper vertical dimension of occlusion must be established for the correct and comfortable formation of the sound *s*. Silverman[8] uses the enunciation of the sibilant *s* as a phonetic means for determining vertical dimension. Also, the forming of *s* may be used as an effective procedure for verifying the vertical relation established by other means. When *s* is pronounced, the upper and lower teeth are separated from each other by only 1 or 2 mm. When the patient says "sixty-six" and the vertical dimension of occlusion is too great, the teeth will come into contact, causing clicking.[1] Discovery of this error in the wax trial denture gives the dentist the opportunity to make the necessary corrections.

T, D, N, and L.—The palatolingual consonant sounds *t, d, n,* and *l* are of interest to dentists. The sagittal section diagram and palatograms of these sounds demonstrate that the rugae area of the palate is critical to their formation (Fig. 2).

The tongue must be placed firmly against the anterior part of the hard palate to produce these sounds. Therefore, the problem arises as to whether rugae should be reproduced in the denture base. Slaughter[9] believes that the smoothness of the denture is disturbing, and without rugae the tongue loses its capacity for local orientation. However, Landa[1] states that the rugae are useless or even detrimental to most patients because of the necessary additional thickness of the denture. This excessive thickness causes phonetic difficulty because of the premature contact of the tongue with the denture base when the palatolingual sounds *t, d, n,* and *l* are pronounced. Where no loss of tissue has occurred, as on the palatal surface, the denture should be thin so tongue space will be reduced as little as possible.[10] The objection is not to rugae as such but to the additional thickness they add to the denture base. Thus, Landa[1] reproduces rugae in upper removable partial dentures when the vertical dimension is increased and additional space is provided for the tongue.

PALATOLINGUAL SOUNDS FORMED BY TONGUE AND SOFT PALATE

This group of sounds includes *k, ng,* and *g* (hard). The palatogram of the sound *k* is typical of the group (Fig. 3). The sound is formed by raising the back

Fig. 1.—Palatograms of *s, sh,* and *th*. Note that an increase in the width of the channel corresponds to an increase in shallowness of the groove in the tongue, causing softening of *s* to *sh* and to *th*. A palatogram is a representation of the palate. The dark portions indicate points of lingual occlusion. (After Borden, R. C., and Busse, A. C.: Speech Correction, New York, 1925, F. S. Crofts & Co., Inc., by permission of Appleton-Century-Crofts, Inc.)

Fig. 2.—*A*, A sagittal section diagram of *t*, *d*, *n*, or *l*. These palatolingual sounds are similar in their mode of formation. Each requires firm contact of the tip of the tongue against the rugae. *B*, A palatogram of *t*, *d*, or *n*. The palatograms of these three palatolingual sounds cannot be distinguished from each other. *C*, A palatogram of *l*. This palatogram is somewhat different from that of *t*, *d*, or *n* but is similar in the essential factor of tongue contact against the rugae area. (After Borden, R. C., and Busse, A. C.: Speech Correction, New York, 1925, F. S. Crofts & Co., Inc., by permission of Appleton-Century-Crofts, Inc.)

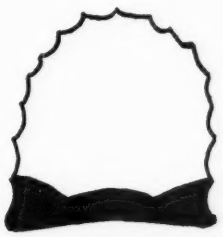


Fig. 3.—A palatogram of *k*. (After Borden, R. C., and Busee, A. C.: Speech Correction, New York, 1925, F. S. Crofts & Co., Inc., by permission of Appleton-Century-Crofts, Inc.)

of the tongue to occlude with the soft palate and then suddenly depressing the middle portion of the back of the tongue, releasing the air in a puff. If the posterior border of the upper denture is overextended or does not make firm contact with the tissue at the posterior palatal seal, the *k* becomes altered toward the German *ch* sound.[2]

SOFT PALATE IN SPEECH

The soft palate must rise and form a competent velopharyngeal sphincter closing the nasopharyngeal space in all speech sounds except *n*, *m*, and *ng*. When the soft palate is inactive, the space remains open, causing a nasal tone. An overextended maxillary denture may cause irritation of the velum, with subsequent stiffening of its muscles. In some patients, the first encounter with a correctly extended maxillary denture may cause tightening of the muscles of the soft palate, giving the same result as an overextended denture. In the first instance, the trouble is easily corrected by reducing the extent of the denture. However, if the trouble is of psychogenic origin, the difficulties can be overcome by patient education about the necessity of a relaxed musculature for clear enunciation.[7]

LINGUODENTAL SOUNDS

The consonant *th* is representative of the linguodental group of sounds and may present phonetic difficulties for denture patients. The tip of the tongue, com-

parable in thickness to the interocclusal distance, is grasped between the incisal edges of the upper and lower incisor teeth (Fig. 4). Air is forced into the channel formed by the palate and the dorsum of the tongue, then the tip of the tongue is retracted into the oral cavity. As the air escapes through the space created by the retraction of the tongue, the sound *th* is formed.[1] The palatogram aids in visualizing the production of this sound (Fig. 1).

Phonetic abberations of the sound *th* result from errors in the interarch space or the labiolingual position of the anterior teeth. An inadequate interocclusal distance may cause a sensation of tongue biting when *th* is articulated. The patient may tend to place the tip of the tongue *behind* the anterior teeth instead of *between* them and *th* will be pronounced *t*. *Th*in will become *t*in.[12] Compare the palatogram of *th* (Fig. 1) with the palatogram of *t* (Fig. 2). Similarly, *th* is pronounced *t* when the anterior teeth are set too far lingually. The tongue becomes pressed against the lingual surfaces of the upper and lower teeth and against the linguogingival margin of the upper anterior teeth. The sound *t* will result from this relation of the tongue and teeth (Fig. 2).

A patient with an exceptionally retruded mandible requires an arrangement of anterior teeth with a large horizontal overlap. The linguodental sounds are

Fig. 4.

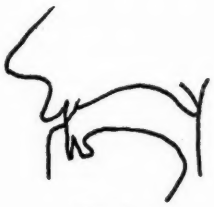


Fig. 5.

Fig. 6.

Fig. 4.—Sagittal section diagram of *th*. The tip of the tongue is placed between the incisor teeth. (After Borden, R. C., and Busse, A. C.: Speech Correction, New York, 1925, F. S. Crofts & Co., Inc., by permission of Appleton-Century-Crofts, Inc.)

Fig. 5.—Sagittal section diagram of *f*. The lower lip is brought into contact with the incisal edges of the upper anterior teeth. (After Borden, R. C., and Busse, A. C.: Speech Correction, New York, 1925, F. S. Crofts & Co., Inc., by permission of Appleton-Century-Crofts, Inc.)

Fig. 6.—Sagittal section diagram of *b*, a bilabial sound. (After Borden, R. C., and Busse, A. C.: Speech Correction, New York, 1925, F. S. Crofts & Co., Inc., by permission of Appleton-Century-Crofts, Inc.)

difficult for such a patient to pronounce. However, a palatal addition can be made lingually to the upper anterior teeth to establish the proper physical conditions for the production of these sounds.[13]

LABIODENTAL SOUNDS

The labiodental sounds *f* and *v* are formed by raising the lower lip into contact with the incisal edges of the maxillary anterior teeth and forcing air through the interproximal spaces between these teeth and through the irregular gaps between the edges of the teeth and the occluding surface of the lower lip (Fig. 5). The only difference between these two sounds is that *f* is voiceless while *v* is voiced.

A correct labiodental sound depends upon the labiolingual and superoinferior position (occlusal plane) of the maxillary anterior teeth. Placing the maxillary anterior teeth too far lingually with reference to the lower lip muffles the sound *f* by allowing the lower lip to slide over the labial surfaces of the upper teeth.[2] Distortion of *f* also occurs when the maxillary anterior teeth are placed too far labially, which allows the lower lip to slip up under the incisors.[12] When these teeth are properly placed for esthetics, these problems will rarely be encountered.

A second group of errors stems from the improper location of the occlusal plane. If the maxillary anterior teeth are set below the proper plane, the lower lip will make premature contact with the incisal edges of these teeth and cause discomfort or the lip will assume a more comfortable position behind the incisors. Conversely, if the maxillary anterior teeth are set too far above the proper plane of occlusion, the lower lip will not reach the incisal edges of these teeth and cause the labiodental sounds to be indistinct.[1] The critical factors in labiodental sounds are the positions of the maxillary anterior teeth.

BILABIAL SOUNDS

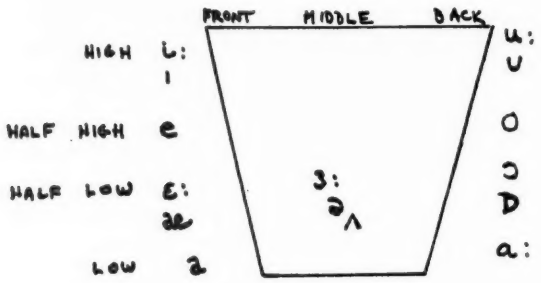
The bilabial sounds *b*, *p*, and *m* are formed by a stream of air coming from the lungs which meets with no resistance along its entire path until it reaches the lips. To form *b* and *p*, the lips are closed and then opened suddenly with the expulsion of the air (Fig. 6). The sound *m* is produced in a similar manner except that the air escapes in part through the nose as a nasal sound.

The normal formation of the bilabial sounds depends upon a correct interarch distance and a correct labiolingual positioning of the anterior teeth. If the interarch distance is excessive, the patient cannot close the lips comfortably to form the air seal, while when sufficient interarch distance exists, the lips contact prematurely. Either of these two errors leads to a distortion of the bilabial sounds.

A similar problem exists in the labiolingual positioning of the anterior teeth. When the teeth are placed too far labially, the lips do not meet comfortably; with a lingual displacement of the anterior teeth, the lips meet prematurely. Therefore, the pronunciation of the bilabial sounds should be used to check the vertical jaw relation and to make sure that the lips meet comfortably without premature contact of the occlusion rims.[1] Similarly, the labial fullness of the occlusion rims should be observed during the pronunciation of the bilabial sounds so that a comfortable meeting of the lips can be attained.

VOWELS

Vowel sounds are produced by the vocal cords imparting their vibrations to the expiratory column of air with the tongue and lip position imparting the overtone structure.[14] The vowels are continuous, as distinguished from the consonants, which are produced by a sudden check of the expiratory column of air by closure of one of the musculoskeletal valves.[1]



	Front	*Middle*	*Back*
High	i (*r*ead) ɪ (*s*ix)		u (root) ʊ (book)
Half-high	e (baker)		o (omit)
Half-low	ɛ (set) æ (man)	ɜ (girl) ə (*a*bout) ʌ (*u*pper)	ɔ (mortar) ɒ (dog)
Low	a (*a*ft)		*a* (f*a*ther)

Fig. 7.—The upper line of the keystone labeled front, middle, and back represents, respectively, the premaxilla, the palatine process of the maxillae, and the soft palate; these are the horizontal positions occupied by the highest part of the tongue in the oral cavity in pronouncing the various vowels. The vertical components of the keystone labeled high through low represent the vertical position occupied in the oral cavity by the highest part of the tongue in pronouncing various vowels. (After Roth, G. J.: Am. J. Orthodontics 26:1-23, 1940.)

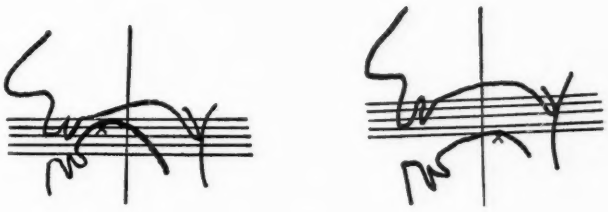
Although there are many vowel classification systems, the one based on the horizontal and vertical position of the tongue in the oral cavity is of most value from the dental viewpoint. If for each vowel sound the horizontal and the vertical position of the highest part of the tongue in the oral cavity is known, the exact position of the tongue can be located from the given sound.[15] This system of classification is graphically depicted by Roth[14] in his keystone vowel chart (Fig. 7). Examination of sagittal section diagrams for a high front vowel (*i* in s*i*x) and a low back vowel (*a* in f*a*ther) further clarifies this system of vowel classification (Fig. 8).

Boghosian and Spangenberg[16] have shown that after the insertion of a prosthesis, the greatest alteration in the quality of vowel sounds occurred in the front of the mouth with high or half-high vowel sounds. Therefore, they suggest that rugae should not be placed on dentures, so that the anterior part of the denture

base can be as thin as possible, and that major connectors in maxillary removable partial dentures should be placed posterior to the premaxillary region.

Whether or not the alteration in the quality of vowel sounds is clinically significant is debatable. However, the dynamics of the production of the palatolingual consonant sounds demands adequate tongue space in the anterior part of the palate. Therefore, a thin denture base in the anterior region is necessary, primarily to the production of accurate palatolingual consonant sounds and secondarily to ensure the correct quality of the high vowel sounds formed in the front of the mouth.

Vowel sounds are also affected adversely by setting the lower anterior and posterior teeth lingually off the ridge. The tongue contacts the lower teeth and their alveolar processes in most vowel sounds. Setting the lower teeth too far lingually crowds the tongue in the floor of the mouth and makes the production of vowel sounds awkward.[1] When the tongue is broad, as after a prolonged edentulous period, crowding of the tongue may be experienced even when the teeth are set in the correct positions. A cross-bite arrangement of the posterior teeth may be necessary for such patients.



A. *B.*

Fig. 8.—*A*, A sagittal section diagram of a high front vowel, *i* as in *s*ix. Note that the vertical position occupied in the oral cavity by the highest part of the tongue *(X)* is high while the horizontal position is front. *B*, A sagittal section diagram of a low back vowel, *a* as in f*a*ther. Note that the vertical position occupied in the oral cavity by the highest part of the tongue *(X)* is low while the horizontal position is back. (After Borden, R. C., and Busse, A. C.: Speech Correction, New York, 1925, F. S. Crofts & Co., Inc., by permission of Appleton-Century-Crofts, Inc.)

The tongue does not touch the palatal vault in forming most vowel sounds. There are, however, two exceptions: *a* as in b*a*ker and *e* as in h*e*ad. In these instances, the sides of the tongue touch the molar and premolar teeth and adjoining mucosa. Here, as in the prevention of stigmatismus lateralis, there is the need for palatal eminences in the molar and bicuspid regions.[11]

Aside from the several situations described, difficulty is not encountered with vowel sounds in denture patients. If the denture is correct phonetically for the consonant sounds, the vowels present little or no trouble.

A common test utilizing the vowel sound *a* as in f*a*ther is useful in locating the vibrating line for correct placement of the posterior palatal seal. The soft palate is raised when this vowel sound is emitted, and a velopharyngeal sphincter is formed permitting the vibrating column of air to pass only through the oral cavity.[14] The soft palate is activated, and the vibrating line becomes clearly demarcated.

DISCUSSION

Various dentists stress different factors in their attempts to produce phonetically accurate dentures. Pound[18] states that phonetics is controlled entirely by esthetics and that an exact replacement of lost natural oral structures eliminates phonetic problems. Others[2] have shown that if mechanical and esthetic requirements are met, phonetics rarely presents a problem. Kessler[4,5] stresses the importance of compensatory movements by the patient and training with pre-extraction tape recordings of the natural speech of the patient. A satisfactory solution probably involves a blending of these approaches.

A few factors, namely, the correct vertical dimension, the occlusal plane, the contour of the palate, and the positioning of the anterior teeth, are common requirements for the production of most speech sounds. Therefore, the vertical dimension of occlusion should be checked by the technique of Silverman[8] or by the simple tests suggested in this article. Similarly, the occlusal plane should be checked phonetically with the labiodental sounds. The contour of the palate should be restored to the same contour and bulk of material it possessed originally.

With the increasing tendency toward an irregular arrangement of anterior teeth, the dentist must be certain that a phonetic impediment is not introduced through the spacing or overlapping of the anterior teeth. Finally, if speech problems persist in spite of a phonetically correct denture, the dentist must embark on a program of patient education.

SUMMARY

The importance of phonetics in denture prosthesis has been discussed, the formation of sound units of dental interest has been presented with possible factors that cause phonetic difficulty with these sounds, and a practical approach to the problem of phonetics in denture construction has been proposed.

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VARIATIONS IN LOCATION OF ARBITRARY AND TRUE HINGE AXIS POINTS

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CASTS ARE OFTEN TRANSFERRED to the articulator by arbitrary means, because the method of locating the true hinge axis is thought to be a complicated and time-consuming procedure. Many authors[1-7] recommend the use of the face-bow and describe techniques for marking the hinge axis point arbitrarily.

This is a report of a study to determine the variations in the location of the true hinge axis points from the location of the hinge axis points determined by arbitrary means.

METHOD OF TRUE HINGE AXIS LOCATION

The Lauritzen Research Group at the University of Oregon Dental School, Postgraduate Department, has developed a technique and armamentarium to locate the true hinge axis easily and accurately. The method had to be easy, accurate, and practical to be feasible and applicable to everyday practice.

A special tray is used to secure attachment to the mandible of the hinge axis locator. This tray consists of the anterior part of a rim lock tray. A stem is soldered to it anteriorly and superiorly. The tray is secured to the mandible with an alginate impression material. The lightweight hinge axis locator is attached to the stem which projects from the tray (Fig. 1). A 1 cm. square piece of millimeter graph paper is attached to the skin in the region anterior to the tragus of the ear. The needle of the hinge axis locator is moved close to the graph paper, but not to contact it. With the thumb on the point of the chin, the dentist guides the mandible to open and close in the terminal hinge relation. The needle will be seen to describe a segment of a circle close to the graph paper. The needle is then moved toward the center of the circle, until the needle does not move in an arc but merely rotates. This is verified under magnification. Thus, the hinge axis point has been located.

Since the integument in the area is readily movable and influenced by the position of the head rest, all patients are positioned erect in the chair with no head rest support while this point is marked. The graph paper is carefully removed. The mandible is placed in the terminal hinge relation. The locator needle is retracted from its proximity to the skin. Marking material is placed upon the tip of the needle, and the needle is carefully brought into contact with the relaxed skin. Thus, an accurate marking is obtained. The process is repeated on the opposite side of the face.

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For this study, the above procedure was followed on 50 patients, so 100 hinge axis points were located and recorded.

METHODS OF ARBITRARY HINGE AXIS LOCATION

Schlosser[2] described a method using palpation of the outer tissue integument to locate the position of the condyles while the patient is opening and closing the mouth. Another method he describes is to align a flexible ruler with the upper margin of the external auditory meatus and the outer canthus of the eye. A line

Fig. 1.—The hinge axis locator is in place.

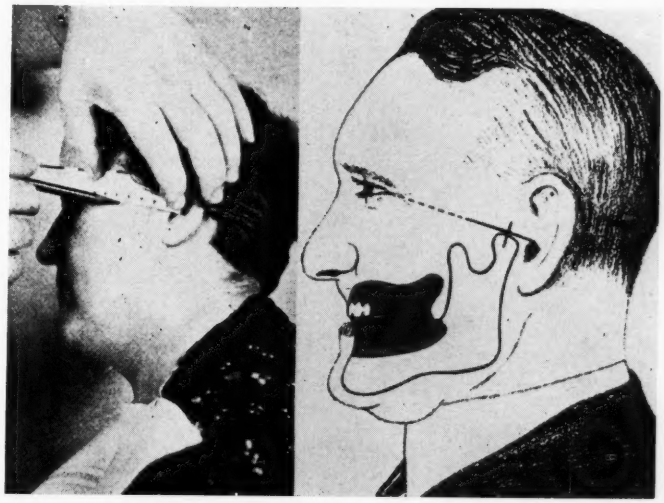

Fig. 2.—A method of locating the hinge axis point. (From Schlosser, R. O.: Complete Denture Prosthesis, ed. 2, Philadelphia and London, 1946, W. B Saunders Company, p. 205.)

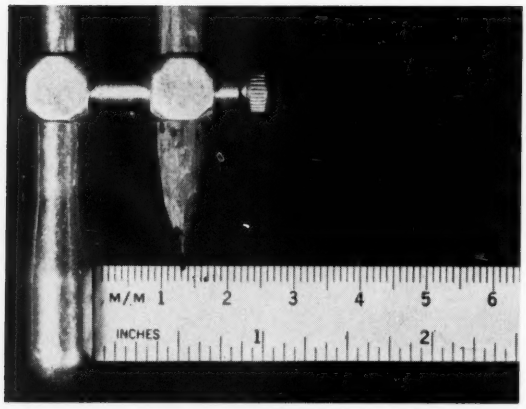

Fig. 3.—The Richey condyle marker.

about 25 mm. long is drawn in front of the meatus. At a point about 13 mm. in front of the tensed anterior margin of the meatus, a line is drawn crossing the first line at right angles (Fig. 2).

Brandrup-Wognsen[7] utilized the following method: "On a line extending from the tragus to the lateral angle of the eye, a point is marked at about 12 mm. in front of the posterior margin of the most prominent point of the tragus. The presumed condyle axis is supposed to pass through these points which are called the approximately determined condyle points." He also stated that the hinge axis is so near to the approximately determined axis that using a complicated form of registration is scarcely necessary for practical work.

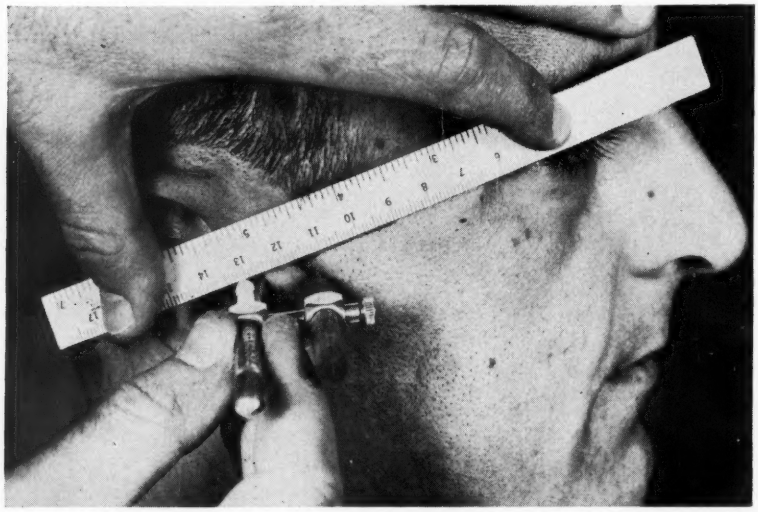

Fig. 4.—The Richey condyle marker is in position in relation to the ruler, which is directed to the outer canthus of the eye.

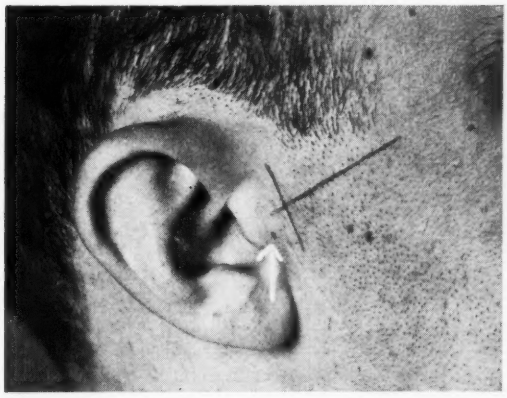

Fig. 5.—The arbitrary axis point is marked on the face by the intersection of the two lines. The arrow indicates the true hinge axis point.

For the purpose of standardizing the arbitrary hinge axis location on the 50 patients used in this study, a method suggested by Prothero[8] was used. A Richey condyle marker (Fig. 3) was employed by first inserting the bulbous end of the metal piece into the external auditory meatus. A ruler was then placed from the top of the marker to the outer canthus of the eye, and a line was drawn (Fig. 4). The condyle marker was then rotated to make an intersecting line 13 mm. from the anterior side of the metal part of the marker.

This procedure was executed on both sides of the face, and the points thus located were designated as the arbitrary hinge points. Then the variation in position of the actual hinge axis point from the arbitrary hinge axis point was carefully measured and recorded (Figs. 5 and 6).

RESULTS

The results are shown in Table I and Fig. 7. Only 33 per cent of the true hinge axis points were within a 5 mm. radius of the arbitrary point.

DISCUSSION

Schallhorn[9] found that: "In over 95 per cent of the subjects with normal jaw relationships, the kinematic center lies within a radius of 5 mm. from the arbitrary

TABLE I. THE RELATIVE LOCATION OF 100 TRUE HINGE AXIS POINTS TO THE POINTS DETERMINED BY AN ARBITRARY TECHNIQUE.

	DISTANCE FROM THE ARBITRARY POINT					
	2 mm.	2-4 mm.	4-6 mm.	6-8 mm.	8-10 mm.	Over 10 mm.
Percentage	6	15	19	15	27	18

center." Beyron,[10] in a similar study, found that approximately 87 per cent of the located points were within a 5 mm. radius from the arbitrary point. Our results differ markedly, since only 33 per cent of the actual hinge points were within a 5 mm. radius of the arbitrary point. Although Beyron's[10] findings differ from ours, he still emphasizes the importance of locating the "kinematic axis."

It could be argued that the location we chose for the arbitrary point was different than the points selected by others. Therefore, the following procedure was

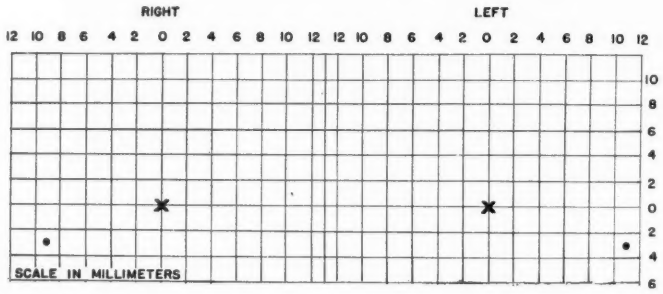

Fig. 6.—The record made of an individual patient. Cross marks indicate the location of the arbitrary axis points; dots, the location of the true hinge axis point.

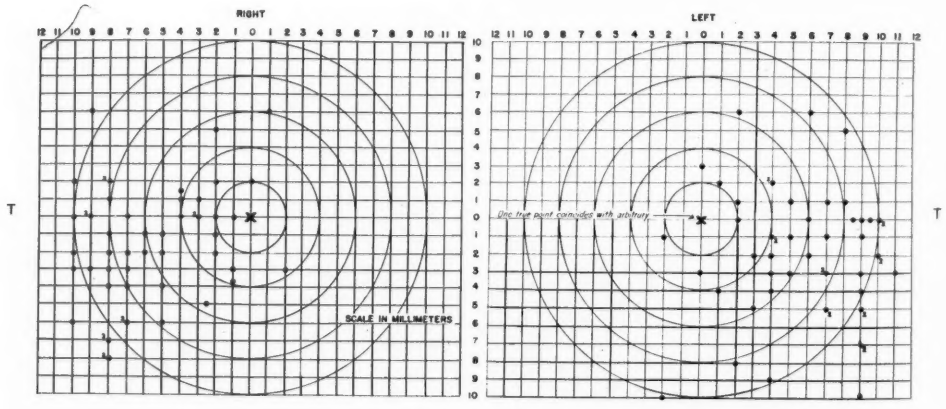

Fig. 7.—The records of the arbitrary point (cross marks) and the true hinge axis point (dots) plotted on graph paper. In this study of 50 patients, 60 per cent of the true hinge axis points are from 6 to 12 mm. away from the arbitrarily marked point.

carried out: A cardboard disk with a 5 mm. radius was placed over the area of greatest concentration of the true hinge axis points indicated on Fig. 7. This identical area was covered on both the left and right sides. When the disk was placed up to it, it covered the largest number of actual hinge points. Only 70 per cent of the points were covered. The center of this disk (which is also the epicenter of the greatest concentration of actual hinge points) placed the new arbitrary point 6 mm. posterior and 2 mm. inferior to our previously selected arbitrary point.

This demonstrates that the use of any method of locating the hinge points arbitrarily might incorporate errors in mounting too gross to be tolerated.

CONCLUSIONS

In locating the true hinge axis points, we found that 67 per cent were from 5 to 13 mm. away from the arbitrarily marked hinge points. Therefore, arbitrary marking (using surface anatomic landmarks) may introduce severe errors in mounting of casts on an articulator. These errors will introduce error in occlusion if the centric jaw relation record is made with a separation between the upper and lower teeth.

The careful location of the actual hinge axis points, instead of depending upon an arbitrary marking, is recommended to avoid potential sources of error in mounting casts.

SUMMARY

A study was undertaken to determine the extent of variation in positions of actual hinge axis points from arbitrarily marked hinge axis points. A standardized method of locating the arbitrary point was described. Out of the 100 true hinge axis points located and recorded, 67 per cent were found to be 5 to 13 mm. away from the arbitrarily marked point.

The arbitrary center was changed to a position from which the maximum number of points could be found within a 5 mm. radius. Then it was noted that only 70 per cent of the true hinge axis points were within the 5 mm. radius. Therefore, the accurate location of the true hinge axis points is recommended.

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RELIEF CHAMBERS IN COMPLETE DENTURES

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THE USE OF RELIEF CHAMBERS in complete dentures is an open question. Therefore, a questionnaire was submitted to dental educators in the United States, Canada, and other countries inquiring about their practices in the use of relief chambers in dentures.

REASONS FOR RELIEF

Some dentists[1-4] advocate relief because of the differences in resiliency of the tissues of the palate and the alveolar ridges. The central area may act as a fulcrum for rocking of the denture base. They feel that unless some procedure is undertaken to provide relief, the denture will be dislodged under stress.

Other areas that are recommended for relief include the incisive papilla, the incisive foramen, the entire length of the median raphe, the rugae, and the anterior and posterior palatine foramen.[1]

Other justifications for relieving the median raphe are compensation for anticipated resorption of the alveolar processes, the theory that impression materials are under greater pressure in this region,[2,5] and the pattern of curing shrinkage of the acrylic resin denture base which causes the central palatal area to emerge abnormally high.[2]

SHAPE OF RELIEF

The methods used to determine the outline of the relief range from that of designing an arbitrary shape to include any or all of the anatomic structures mentioned to that of locating the hard areas by inspection and palpation. The relief is accomplished by scraping the corresponding parts of the impression to the depth of 1 mm. or more (0.04+ inch) or by covering the same areas of the cast with tinfoil or other metal. Making the impression with a relatively viscous material confined in a close-fitting tray is thought, by some, to add a measure of "automatic" relief over the hard tissue by displacing the softer tissue.[2,5]

Recent research and the application of basic science to the problems of relief have raised questions as to the value of the routine use of relief in dentures. Stanitz[6] showed that the retentive force was directly proportional to the area of the surface of the denture and inversely proportional to the thickness of the fluid film.

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Campbell[7] made clinical measurements of the retentive force of denture bases of various designs. The introduction of a relief chamber decreased the retention. The decrease was more pronounced as the extent of the relief was increased. This effect was attributed primarily to an increased thickness of the fluid film.

Lammie[4] calls attention to two optimal conditions, a salivary meniscus of less than 0.0005 inch in thickness and a completely intact, extremely thin fluid film. Therefore, he cautions that all "unnecessary relief" be avoided, that relief be of minimum extension and thickness, and that certain routine types of relief be eliminated. Nagle and Sears[5] state that if it were not for certain other considerations, the ideal denture base would be in intimate contact with as large an area of tissue as possible to obtain the maximum retention. They note that frequently no relief is necessary.

Landy's[8] only concession to relief is in regard to the torus palatinus. If a slight discrepancy in the fit of the denture resulting from distortion of the denture base causes the denture to impinge upon the torus, a slight relief may be provided. Otherwise, he strives through the use of free-flowing impression materials for the most accurate possible reproduction of the shape of the mucosa and, thus, the thinnest attainable fluid film.

INFORMATION FROM QUESTIONNAIRE

A questionnaire was sent to fifty dental schools in the United States and Canada and to eleven schools in European countries and Israel. Interest was expressed as to whether relief chambers are used routinely or only under special circumstances and, if routinely, the shape, extent, and structures included, the approximate thickness, and the method of accomplishing the relief. A space was left for an optional short comment on the reasons for including, or not including, a relief chamber in dentures.

Use of Relief by Dental Schools.—Of fifty-three schools reporting (87 per cent of those questioned), three schools (6 per cent) never employ relief chambers under any circumstances in complete upper dentures. Thirty-one (58 per cent) of the schools use relief in special situations. Relief areas are incorporated routinely by nineteen schools (36 per cent). When considered apart from the others, the eleven overseas schools include five which use relief only under certain specific conditions, five which employ relief routinely, and one which never uses relief.

Tissues Relieved.—There is scarcely any uniformity among the nineteen schools with regard to what tissues of the palate are afforded relief. At six schools, relief is included routinely for the incisive papilla, the incisive foramen, the rugae, and the median raphe. Two schools provide routine relief for the incisive papilla, the incisive foramen, and the median raphe, while two schools only relieve either the incisive papilla and the incisive foramen or the incisive papilla and the median raphe. In addition, seven other combinations of structures were reported to be routinely relieved by at least one dental school. A summary of the structures involved in routine relief in the various schools is found in Table I.

Variation in Methods.—The methods of accomplishing the relief also vary widely. Twenty-three schools place tinfoil on the cast, while five employ relief

metal. Seven obtain relief by scraping the impression and four by grinding the finished denture. Three schools use their impression technique to provide "automatic" relief over the harder, more unyielding tissues.

The depth of the relief chambers varies considerably among the schools. This range is from 0.001 inch in thickness as reported by three schools to 0.06 inch as mentioned by one. The most "popular" dimension is 0.01 inch, which is in use at six schools. Six other distinct thicknesses were cited, three of which are employed at one school only. Two clinics construct relief of the thickness of one layer of dental roentgenogram foil and two other schools of the thickness corresponding to that of #7 Ash's metal (0.02 inch). At three schools, the appropriate depth of relief is estimated by palpation of the patient's palate and at one school by use of pressure indicator paste. The approximate thicknesses used are shown in Table II, the techniques for attaining relief in Table III.

TABLE I. TISSUE INCLUDED IN ROUTINE RELIEF CHAMBERS

NO. OF SCHOOLS	INCISIVE PAPILLA	ANTERIOR PALATINE FORAMEN	RUGAE	MEDIAN RAPHE	CENTRAL FLAT PART, HARD PALATE	LATERAL TORI OF PALATE
6	X	X	X	X		
2	X	X				
2	X	X		X		
2	X			X		
1	X	X	X	X	X	
1	X				X	
1	X	X		X	X	
1	X	X		X		
1	X	X	X			X
1	X					
1		X				

Variation in Size.—There were also rather wide differences in the shape of the relief. The relief chambers are made roughly the shape of a triangle with the apex directed anteriorly in seven clinics, whereas in two others, a triangle is used but with the base oriented anteriorly. Four schools use a more or less oval, elongated relief shape, and four use a small, circular relief in the anterior part of the palate to accommodate only the incisive papilla and foramen. No "characteristic" shape of relief is used at the three schools in which the shape is determined by palpation of the tissue.

Optional Comments.—Certain comments were offered optionally on the policy in regard to relief areas. At one school, relief is not incorporated because its use has not been justified as yet. Routine inclusion of relief is avoided by some because they believe that it has an adverse effect upon retention, that valuable tissue contact is thereby lost, or that there is a detraction from the benefits obtained through a static impression technique. Others do not employ relief as a matter of course because they are skeptical about whether it will perform the function intended, it does not appear to be helpful, or stability and retention seem optimal without

TABLE II. THICKNESSES USED IN RELIEF (WHETHER OR NOT ROUTINE)

THICKNESS	NO. OF SCHOOLS
0.001 inch	3
0.003 to 0.009 inch	3
0.004 inch	1
0.007 inch	1
0.01 inch	6
0.02 inch	2
0.03 inch	1
0.04 inch	2
0.06 inch	1
Equivalent to one thickness of x-ray pack foil	2
Equivalent to #7 Ash's metal	2
Variable, as estimated by palpation, indicator paste	4

it. Two schools offered the opinion that since the palate is basal bone, it should logically be utilized as an important secondary bearing area. One comment was that routine relief is empirical, and it was noted by several clinics that this policy had been abandoned as long as 15 years ago. Another reason given was that the curing shrinkage of acrylic resin makes the denture base self-relieving.

The greatest number who commented on their purpose in incorporating relief said that pressure is reduced over hard, unyielding surfaces covered by thin mucosa or that the forces of mastication that displace unequally the hard and soft tissues are thus counteracted. Several stated that their aim is to improve the support or stability of the denture base or to prevent the development of a fulcrum upon which the denture will rock when resorption of the ridges occurs. A reason mentioned by those who favor routine relief is avoidance of pressure on nerves, blood vessels, and other sensitive structures.

DISCUSSION

The most striking feature of this survey is the lack of unanimity of opinion on the subject of relief chambers. Slightly less than two-thirds of those who answered the questionnaire do not instruct their students in the use of relief as a mandatory denture procedure. Several schools have ceased to employ it altogether. On the other hand, slightly more than one-third teach the routine provision for relief. Both sides marshal various justifications for their respective viewpoints.

TABLE III. METHODS OF ACCOMPLISHING RELIEF (WHETHER OR NOT ROUTINE)

HOW ACCOMPLISHED	NO. OF SCHOOLS
Tinfoiling	23
Scraping impression	7
Grinding finished denture	4
Impression technique	3
Relief metal	5

The tradition of some type of space between part of an upper denture base and the overlying palatal tissues has been a strong one, and "vacuum chambers" have been the chief reliance in the retention of maxillary dentures for more than half a century.[9] A relief chamber is not the same as a vacuum chamber and, moreover, it exists for a different purpose. Dentists tend to feel that a relief chamber is not related to retention, only to stability, and that the depression in the denture base does not create a "vacuum" as did, presumably, the traditional vacuum chamber. Furthermore, the shape of the relief chamber varies with existing conditions, and its thickness, as ordinarily constructed, is less than that of the vacuum chamber.[2]

The *Glossary of Prosthodontic Terms*[10] lists the term "suction chamber" as objectionable, but as the equivalent of "relief chamber." The latter is defined as "a recess in the impression surface of a denture to reduce or eliminate pressure from that specific area of the mouth."

Hyperplasia of the tissue underlying relief chambers has been noted. Even though the reason for the use of relief chambers differs from that for the vacuum chamber, many patients have proliferated palatal tissue under the relief chamber. This hyperplastic tissue often fills the entire space provided by the relief (Fig. 1). The negative pressure is thought to stimulate the proliferation of the tissue.

It would seem that the most logical method for determining the tissue to be included in relief would be by palpation of the "hard areas" and by transfer of them with great care, in some way, to the master cast. However, many dental clinics rely on more or less set patterns differing from each other enough in design that one might conclude that some must trespass on "soft" tissues. Palpation also presupposes the possibility of determining with some degree of accuracy from the "feel" of the tissues significant qualities, such as thickness and resilience, and subsequently translating these deductions into the exact terms of size and shape of a relief chamber.

It has been shown[7] that the presence of a relief chamber, resulting in the thickening of the fluid film in that region and a reduction in the surface area of the denture in close proximity to the tissues, materially lessens the retentive forces. Moreover, the larger and deeper the relief, the poorer the retention. In the case of a palateless denture, retention is more drastically reduced. This same work brought out the fact that a border seal definitely enhances retention. Therefore, one might speculate that a denture which includes a border seal and a relief chamber and exhibits good retention might tend to lose this retention more rapidly than would otherwise occur after resorption of the ridges had begun. The border seal would be weakened, and the smaller effective contact area of the palate and the thicker fluid film would be acting unopposed to the detriment of retention.

Moreover, utilizing the basal bone of the hard tissues of the palate should tend to reduce the forces upon the residual ridges, which are prone to resorption. The incorporation of a relief chamber in the upper denture reduces the total area of support of the hard palate, and the force is increased on each remaining unit of surface area. Furthermore, when the denture is pressed into the palate, the soft tissues will move under the force until contact is made with the hard

Fig. 1.—The palatal tissue has proliferated into the relief chamber, thus eliminating the entire space.

tissues of the ridges. Thus, when the vulnerable tissue of the residual alveolar ridges comes under undue stress, the setup is potentially detrimental to the life of the residual alveolar bone. Likewise, one reason for the clinical observation that the lower ridges are resorbed at a faster rate than the upper ridges is that there is no supporting area analogous to the palate in the mandible.

Another speculation in this regard is related to the study in which force was applied to dislodged denture bases of various designs and under differing conditions of contact.[7] The anterior parts of the baseplate could not be pulled down by any practical force which could be utilized, whereas the posterior portions were relatively easy to dislodge. These tests suggest that a relief chamber confined to regions of the palate forward of the center of gravity, such as the incisive papilla, would reduce retention less than one in a more posterior location.

If optimal retention is dependent upon the thinness of the fluid film and the extent of the area of the denture base in contact with the tissues,[6] the goal of impression making is the most accurate recording of the shape of the mucosal surface. This accuracy would eliminate the use of viscous impression materials and those confined so that "automatic" relief is obtained through greater displacement of the soft than of the hard tissues. Similar points of view were expressed in several comments elicited by this survey. It is difficult to understand how displacement of the tissues at the time of the impression can be transferred accurately to the finished denture when dimensional changes take place in the impression itself, in the cast, and in the resin during processing. However, there was no significant difference in retention between a baseplate made from an impression with a displacement technique and one made from an impression without tissue displacement.[7]

The shrinkage pattern of acrylic resin was used as an argument both for and against the use of routine relief. Skinner[11] has shown that the pattern of curing shrinkage in a maxillary denture is often evidenced by a discrepancy in the palatal region and that reprocessing, as relining a denture, accentuates this

shrinkage. On the other hand, the property of water inbibition characteristic of this base material very nearly compensates for the initial curing shrinkage.[12,13] However, Grunewald, Paffenbarger, and Dickson[14] found that the resin did not demonstrate complete compensation for the curing shrinkage in this manner. Thus, acrylic resin might be considered to be self-relieving to some extent.

Another interesting point in regard to relief chambers is that they are not customarily included in metal-base dentures. Manufacturers* of metal alloys have commented that while it is possible to include relief in a metal base, this is done only upon specific request of the dentist. Relief would sacrifice one of the merits of the material, namely, its ability to portray with a high degree of accuracy the surface of the palate in contact with the denture. According to the fulcrum hypothesis, a metal-base denture, as ordinarily designed without a relief chamber, would have an inherent tendency to rock over the median raphe.

SUMMARY AND CONCLUSIONS

A survey of the status of the use of relief chambers in the construction of complete upper dentures was made by a review of the literature and by a questionnaire returned by the prosthetic departments of fifty-three dental schools. The results indicate that opinions and practices are widely variable, that the question is an open one with many ramifications, and that the basis for much of what is done is in need of further study and appraisal.

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ADDITION OF BACTERIOSTATIC AGENTS TO ACRYLIC RESINS

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THE USE OF PLASTICS which will inhibit pathogenic oral microorganisms appears to be desirable. A bacteriostatic, self-curing acrylic resin used as a filling material theoretically should inhibit caries-producing microorganisms. Anticariogenic properties in the resins used in partial dentures might reduce the incidence of caries in abutment teeth. In theory, bacteriostatic acrylic resin would eliminate many of the microbiologic problems encountered with complete dentures. Most plastics are not bacteriostatic, therefore an agent must be added to the plastic which, upon release, will inhibit microorganisms.

Hedegard[1] reported that among 412 patients with acrylic resin restorations examined 1 to 4 years after the fillings were placed, 15 per cent showed secondary caries on clinical examination and 60 per cent developed dentinal caries after removal of the restorations. Coy[2] observed that of thirty-three direct resin fillings, twelve had to be replaced, ten were acceptable, and caries was present under or around the margins in the remaining eleven after 3 to 4 years.

Docking[3] suggested that proximal caries on abutment teeth might be reduced if the plastic was sufficiently bacteriostatic. Lyon and Chick[4] showed that most of their patients who suffered from denture sore spots had the yeast *Candida albicans* in the oral cavity, while most of those with well-fitting dentures did not show this microorganism. The patients with denture sore spots were treated with sodium caprylate or other antifungal drugs. Improvement was noted in most patients. While the number of patients was low, their results suggested that a denture-base acrylic resin that possesses fungistatic or antifungal properties might prevent secondary infection caused by *C. albicans* in patients with denture sore spots.

Harris and Fisher[5] and Colton and Ehrlich[6] incorporated antibiotics and other chemical additives into self-curing filling acrylic resins and demonstrated bacteriostatic properties of the polymerized plastics. However, there was a rapid loss of bacteriostatic properties after the plastic was fully cured.

Contrary to other reports,[7,8] Turkheim[9] showed that methyl methacrylate is bacteriostatically inert. He noted that if the inert, self-curing acrylic resins were combined with various metal powders such as silver, cadmium, or mercury compound before curing, the polymerized plastic was bacteriostatic under certain conditions.

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METHODS AND MATERIALS

Various plastics were tested to determine their bacteriostatic properties. Self-curing methyl methacrylate denture repair material (Durabase), polyethylene Plexiglas, styrol (Hi-impact), nylon (Xytel), cellulose acetate, polyvinyl chloride (Koroseal, Bakelite),* and various acrylic and phenolic resins were used.

Small strips of the plastic were embedded in agar medium in Petri dishes. With the pour plate method, the agar medium had been previously seeded or inoculated with the test microorganism. With the streak plate method, the agar was not seeded, and streaks of the test organisms were placed perpendicular to the plane of the plastic strip.

The test microorganisms were: *Streptococcus salivarius, Streptococcus faecalis* var. *liquefaciens, Staphylococcus aureus, Staphylococcus epidermidis, Lactobacillus acidophilus, Lactobacillus casei, Clostridium perfringens, Neisseria catarrhalis, Salmonella typhosa, Escherichia coli,* and *C. albicans.* These strains were either American Type Culture Collection strains or a standard laboratory strain of the Department of Medical Microbiology, University of Illinois. The microorganisms were grown on nutrient agar, brain-heart infusion agar, tomato juice agar, and Sabouraud's dextrose agar, according to the nutritional needs of the microorganism. They were incubated at 37° C. aerobically or anaerobically, as suited to the metabolism of the microorganism. After incubation, the zones of microbial inhibition were noted and measured.

Various bacteriostatic agents were added to bacteriostatically inert, self-curing methyl methacrylate denture repair materials. The bacteriostatic agents were quinine hydrochloride, mercurous chloride, cadmium chloride, silver chloride, proflavine, thymol iodine, silver proteinate, colloidal silver, ethyl violet, and a mixture.† This mixture contained as active ingredients 3 per cent propylene glycol, 0.3 per cent boric acid, 0.1 per cent 2-ethylhexanol, 3.2 per cent diisobutyl phenoxyethoxyethyldimethylbenzyl ammonium chloride, and 0.8 per cent dimethylbenzyllauryl ammonium chloride, which were added to the polymer, then mixed with the monomer. The dilution of the agent which showed the greatest bacteriostatic activity was added to 0.5 Gm. of methyl methacrylate polymer and 2.5 ml. of methyl methacrylate monomer.

Acrylic resin disks 15 mm. in diameter were made in glass molds. Control disks containing no additive were also formed. The acrylic resin disks were tested by the pour plate and streak plate techniques 48 hours after polymerization. The following test microorganisms were used: *Staph. aureus, Str. salivarius, Str. faecalis* var. *liquefaciens, Bacillus subtilis* var. *globigii, L. acidophilus, L. casei, C. albicans,* and a mixture of salivary microorganisms. These strains were either laboratory strains or oral isolates.

The plastic disks that proved to be bacteriostatic were taken from the agar plates, washed for 12 hours in running tap water, and dried for 9 days in a desiccator over anhydrous calcicum chloride. Then the disks were retested by the pour plate technique. The zones of inhibition were measured. If residual bacterio-

*Materials were supplied by Associated Plastic Fabricators, Chicago, Ill.
†Corobex, Bex Industries, New York, N. Y.

stasis was noted, the disks were washed, dried, and retested until no bacteriostatic activity was noted.

Modified patch tests for toxicity were made by strapping disks containing additives and control disks with no additives on shaved abdominal areas of guinea pigs. After 2 weeks, the areas were examined. Control disks were placed next to the experimental disks.

RESULTS

All plastic resins tested were bacteriostatically inert. None of the plastics, including the acrylic resins, showed any inhibition of bacterial growth in the tests employing either the streak plate or pour plate method.

Inhibition of Bacterial Growth.—Inhibition of bacterial growth was noted in the methyl methacrylate disks containing 10 per cent cadmium chloride and 10 per cent proflavine and in the mixture containing substituted benzyl ammonium chlorides. Slight inhibition was noted with 10 per cent mild sliver proteinate and 10 per cent quinine hydrochloride incorporated in the acrylic resin disks (Table I).

The proflavine, cadmium, and silver salts discolored the pink acrylic resin and were potentially toxic at the 10 per cent concentration. Hence, their use does not appear to be practical in dental plastics.

None of the other agents tested appeared to have any bacteriostatic activity even at the higher concentrations. The mixture containing the substituted benzyl ammonium chlorides was used at a 1:1,250 concentration of the liquid product, and it was the only agent added that showed residual bacteriostatic activity.

The disks that contained the mixture of substituted benzyl ammonium chlorides also demonstrated no toxicity in modified patch tests on guinea pigs at the 1:1,250 dilution of the additives.

TABLE I. INHIBITION OF BACTERIAL GROWTH BY CHEMICAL ADDITIVES INCORPORATED IN METHYL METHACRYLATE RESIN

ADDITIVE	CONCENTRATION	RADIUS OF ZONE OF INHIBITION (MM.)*			
		STAPH. AUREUS	E. COLI	S. TYPHOSA	B. SUBTILIS
Quinine hydrochloride	10%	1	1	1	1
Cadmium chloride	10%	6	5	3	10
Mercurous chloride	10%	0	0	0	2
Proflavine	10%	5	1	5	8
Ethyl violet	10%	0	0	0	0
Silver proteinate†	10%	0	2	2	2
Thymol iodide	1%	0	0	0	0
Mixture containing substituted benzyl ammonium chlorides	1:1,250	25.5	0	1.4	34.4
Control (no additive)		0	0	0	0

*Average of six samples.
†Mild.

TABLE II. INHIBITION OF BACTERIAL GROWTH BY A MIXTURE CONTAINING QUATERNARY COMPOUNDS INCORPORATED IN METHYL METHACRYLATE RESIN

SAMPLE	DAYS	RADIUS OF POUR PLATE INHIBITION ZONE (MM.)*			
		STAPH. AUREUS	E. COLI	S. TYPHOSA	B. SUBTILIS
Mixture (0.1 ml.)	0†	25.5	0	1.4	34.4
	10	7.6	0	0	15.0
	20	4.5	0	0	8.5
	30	2.5	0	0	4.5
Control (no additive)	0–30	0	0	0	0

*Average of six samples.
†Forty-eight hours after polymerization.

The mixture containing the quaternary compound (substituted benzyl ammonium chloride compounds) appeared to be inhibitory to *Staph. aureus* and *B. subtilis* var. *globigii*. The disks that contained the quaternary compound in the added mixture were not bacteriostatic against *E. coli.* and *S. typhosa.* The large zones of inhibition of 25.5 mm. and 34.4 mm. in radius against *Staph. aureus* and *B. subtilis,* respectively, indicate very strong bactericidal effects.

Duration of Residual Bacteriostasis.—The duration of the residual bacteriostasis was tested. The mixture incorporated in methyl methacrylate was inhibitory to *Staph. aureus* and *B. subtilis* for 30 days after complete polymerization (Table II).

The susceptibility of bacteria isolated from the oral cavity was tested with the bacteriostatic acrylic resin disks. The results obtained with the plastic disks containing the mixture of quaternary and other compounds are seen in Table III.

The acrylic resin disks with the mixture incorporated in them exhibited bacteriostatic activity against the oral bacteria and the yeast *C. albicans.* While this bacteriostasis was not as pronounced as that noted with the commonly used test organisms, *Staph. aureus* No. 209 and *B. subtilis* var. *globigii,* it was almost of the same duration. Considerable bacteriostasis was noted through the thirtieth day against *L. casei* and *C. albicans* but only slightly against *L. acidophilus.*

Acrylic resin disks containing the mixture were tested after two washing and drying periods (20 days) with a mixture of microorganisms isolated from caries susceptible saliva. The pooled microorganisms were cultivated on Rogosa Lactobacillus selective agar, brain-heart infusion blood agar, glucose phosphate agar, and nutrient agar. These microorganisms were not specifically identified but included all of the salivary microorganisms that grew on these media. The plates were poured in duplicate, and one series was incubated anaerobically and the other aerobically.

The mean radius of the inhibition zones of the six samples of the various media was 2.3 mm. on the plates which were incubated aerobically. On the plates incubated anaerobically, the mean zone of inhibition of the salivary microorganisms

TABLE III. INHIBITION OF ORAL STRAINS OF BACTERIA BY A MIXTURE CONTAINING QUATERNARY COMPOUNDS INCORPORATED IN METHYL METHACRYLATE RESIN

SAMPLE	DAYS	RADIUS OF POUR PLATE INHIBITION ZONE (MM.)*			
		STR. FAECALIS	L. ACIDOPHILUS	L. CASEI	C. ALBICANS
Mixture (0.1 ml.) in 0.5 Gm. acrylic resin	0†	3.3	4.5	7.6	4.8
	10	3.0	1.8	3.0	3.7
	20	0	0.8	3.0	2.0
	30	0	0.5	2.6	1.2
Control (no additive)	0–30	0	0	0	0

*Average of six samples.
†Forty-eight hours after polymerization.

was 3 mm. After another washing and 9 days' drying (30 days), the mean radii of the zones of inhibition on the aerobic plates were 1.3 mm. complete inhibition and 2.3 mm. partial inhibition. On the plates incubated anaerobically, the mean radii of inhibition were, respectively, 0.8 mm. complete and 1 mm. partial inhibition. This degree of inhibition is not considered significant.

The microorganisms that grew in the partial zone of inhibition on the plates incubated anaerobically were predominantly Gram-positive cocci in chains. In the zones of partial inhibition on the plates incubated aerobically, the microorganisms were Gram-negative rods, Gram-positive cocci, and Gram-positive rods. These results indicate that the acrylic resin disks containing the mixture were inhibitory to those salivary microorganisms that would grow on the media employed in the tests up to a period of 20 days.

Another quaternary mixture containing 3 per cent propylene glycol, 0.3 per cent boric acid, 3.2 per cent paradiisobutyl phenoxyethoxyethyldimethylbenzyl ammonium chloride,* and 0.8 per cent fatty alkyldimethylbenzyl ammonium chloride† in water was used; it possessed bacteriostatic activity almost equal to the first mixture.

Modified skin patch tests were made on guinea pigs. The abdominal areas of the guinea pigs that were in contact with the disks containing the mixture of quaternary ammonium compounds exhibited as much irritation (or possibly slightly less) than those areas in contact with the control disks of acrylic resin which contained no additive. The low skin reaction to the acrylic resin disks containing the mixture of quaternary compounds was in contrast to the reaction to those disks to which cadmium chloride, silver proteinate, and proflavine were added. Except for a slight paleness in color and a slight retardation of polymerization time, no physical or chemical changes were noted in the plastic disks which contained the quaternary compound mixture in the 1:1,250 dilution.

*Hyamine 1622.
†Trition X-400, Rohm & Haas Co., Philadelphia, Pa.

DISCUSSION

Most polymerized resins are bacteriostatically inert. McCue, McDougal, and Shay[7] noted that self-curing acrylic resin filling material exerted a slight bacteriostatic effect. They explained this effect as probably the result of acid radicals in the incompletely polymerized compounds. Shay, Allen, and Mantz[8] repeated this work using oral microorganisms. They noted only a slight bacteriostatic effect which was explained as probably being the result of the methacrylic content of the self-curing resin.

Our studies showed that self-curing acrylic resin is bacteriostatically inert 48 hours after polymerization. Only incomplete polymers, such as methyl methacrylate in which a high concentration of residual methacrylic acid monomer is present, have been shown to be bacteriostatic.

No physical change was apparent in the plastics to which the bacteriostatic agents were added.

Agents which are bacteriostatic or bactericidal before they are incorporated in a plastic, such as cadmium chloride or sliver proteinate, appear to lose some of their bacteriostatic properties upon incorporation into a plastic. We postulate that these agents must be bound to the plastic during the polymerization process or they are trapped in the plastic. Other agents, such as penicillin, are not bound to the plastic at all and are quickly leached out by washing.

The mixtures containing the quaternary compounds may be satisfactory, for they represent these two extremes. The mixtures are bound to the plastic but they are released slowly in sufficient quantity to be bacteriostatic. In this manner, the bacteriostasis lasts through a 30 day period. Although 30 days of bacteriostasis is not sufficient for clinical use, greater concentration of these chemicals may show bacteriostasis of a longer duration.

Coy[2] noted that none of the filling resins had anticariogenic effects to an appreciable degree. A direct filling resin which would be inhibitory to the oral microorganisms, such as the bacteriostasis exhibited by the plastic disks with the mixture incorporated, would be desirable.

The incorporation of a bacteriostatic agent, such as the mixture used in this work in denture-base acrylic resin, is worthy of further investigation. Problems remain, such as the reaction of the oral flora to a bacteriostatic plastic constantly present in the oral cavity, the longevity of the bacteriostasis in the plastic of complete dentures, and the toxicity of a bacteriostatic plastic to the oral tissue.

The use of a bacteriostatic plastic material in partial dentures appears to be desirable since caries of proximal abutment teeth might be reduced or eliminated. All of these applications warrant further laboratory investigations followed by clinical evaluations.

SUMMARY

Various plastics were tested for bacteriostatic properties, and bacteriostatic agents were added to cold-curing acrylic resin. The findings were:

1. Methyl methacrylate, polyethylene, styrol, nylon, cellulose acetate, polyvinyl chloride, and various acrylic and phenolic resins were found to be bacteriostatically inert when polymerization was complete.

2. Most of the bacteriostatic agents tested were found to be ineffective when added to methyl methacrylate cold-curing acrylic resin.

3. Mixtures containing substituted benzyl ammonium chlorides, propylene glycol, and boric acid were found to impart bacteriostatic properties to methyl methacrylate self-curing acrylic resin. Such plastic disks were bacteriostatic to test organisms and fungistatic to the yeast *C. albicans.*

4. The feasibility of using a bacteriostatic acrylic resin in direct filling and complete and partial denture materials was discussed.

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TROUBLE SHOOTING IN COMPLETE DENTURE PROSTHESIS

Part IX. Salivation, Stomatopyrosis, and Glossopyrosis*

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HYPERSALIVATION in infants during the period of teething is a common occurrence. It occurs also in adolescents and adults with the eruption of the second dentition, particularly the third molars. The third dentition (complete dentures) is no exception to the rule.

SIALORRHEA IN COMPLETE DENTURE PATIENTS

Hypersalivation may become the main complaint of the patient with new dentures, and it may temporarily constitute a major problem. The sialorrhea during the first week may be so persistent and stubborn that the patient may refuse to wear the dentures. When sialorrhea occurs, it usually lasts only several days and gradually tapers off to what may be considered normal. However, in severe instances, which are rare, no material improvement may be observed for days and weeks, and the dentures may fail because the patient can no longer endure the discomfort.

Here, a calm and kind attitude by the dentist is of prime importance. The patient is thoroughly frightened and, at the same time, feels ashamed and dejected because he is unable to control himself. He is in need of the emotional support which the dentist can supply.

Hypersalivation is caused by an increased flow of blood through the salivary glands and their excessive stimulation. Etiologic factors of this syndrome are (1) emotional stress, (2) teething in infants, (3) infectious diseases, (4) inflammatory conditions of the tonsils, (5) dislocation of the mandible, (6) painful eruption of the third molars, (7) chemicotoxic substances (mercury, bismuth, iodides, bromides), (8) digestive disorders, (9) painful afflictions of the oral cavity, and (10) reflex action from stimulation by dentures as foreign bodies. The chief cause for complete denture patients is emotional stress, painful afflictions of the oral cavity, reflex stimulation of the dentures, or any combination of the three. Anxiety, pain, and even mild discomfort in the oral cavity stimulate the salivary glands to increased activity.

Several important causes of excess salivation arising from the dentures are (1) incorrect centric jaw relation registrations, (2) excessive vertical dimension, (3) overextension of denture borders, (4) pain and excessive pressure upon the oral mucosa, (5) pressure upon nerves and their terminal ramifications, (6) exces-

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sive stimulation of the salivary glands by the dentures acting as a foreign body, (7) excessive thickness of the dentures restricting the tongue in its static state, as well as in function, and (8) the patient's anxiety about possible failure of the dentures. It is very easy to imagine the pain, discomfort, and inconvenience that the patient experiences with dentures. Teething in infants, painful eruption of third molars in adults, and mandibular dislocations cause hypersalivation in nearly the same way that an incorrect centric jaw relation and overextension of denture borders engender discomfort and ulcerations. Basically, the etiologic factors in both instances are biologic in nature and, therefore, more or less the same. The mechanism by which they work and the intensity of the stimuli they transmit to the salivary glands may differ somewhat. Therefore, in treating excessive salivation caused by newly constructed dentures, all etiologic factors must be corrected.

Small doses of opiates or atropine sulfate may be desirable for the first day or two in instances of severely excessive salivation. Kind treatment, sympathetic understanding, and appropriate reassurance of the patient are essential because, in some instances, they alone may effect the cure. Miller[1] reports a patient with excessive salivation and glossopyrosis (burning tongue) who was treated successfully by reassurance alone.

XEROSTOMIA, STOMATOPYROSIS, AND GLOSSOPYROSIS

Dry mouth, burning mouth, and burning tongue are seen frequently in people wearing complete dentures. However, complete dentures are not always the etiologic factor. Often, patients with natural teeth, particularly women, are afflicted by this condition. However, the syndrome may be in its incipient stage, and the patient may not inform the dentist of its presence.

From a diagnostic standpoint, it must be determined whether the condition was present prior to the insertion of the dentures, whether the dentures served merely as the precipitating cause, or whether the dentures were entirely responsible for the syndrome. A careful case history will aid in determining the cause.

Xerostomia (dry mouth) may be the result of many factors other than the insertion of new dentures, such as diabetes mellitus, diabetes incipidus, and chronic infection of some or all of the salivary glands. Also, diarrhea, fevers, vitamin A and other vitamin deficiencies, and drugs, such as opiates and derivatives of *Atropa belladonna,* may cause the condition.

It is almost impossible to make a clear-cut diagnosis of the cause of stomatopyrosis (burning mouth). In most instances, it is caused by many complex factors at work simultaneously. Extensive surgical operations in the oral cavity, various diseases of a general nature, disorganization of the endocrine system, nutritional deficiencies, and emotional disturbances may be causal and contributing factors.

Severe burning mouth is found most frequently in women in the menopausal or postmenopausal stage, between 40 and 60 years of age. They usually suffer from psychologic symptoms in conjunction with the menopause. Often, the onset of the syndrome follows extensive surgical operations, particularly those performed on the female sexual organs or in the oral cavity. Whether the mental shock of a general operation or the actual injury to certain nerves and blood vessels in oral operations is the primary cause for this syndrome is difficult to state. However,

the cancerophobia complex in many patients sets in soon after the general operations have been performed. Also, many patients complain of severe burning of the numb areas that result from surgical trauma soon after insertion of dentures.

Allergy to denture-base materials as an etiologic factor or even a contributing factor in the burning mouth syndrome has been vastly overrated. However, some women in the menopausal stage develop *an extreme hypersensitivity* of the oral mucosa to contact with or pressure by artificial restorations. Pressure that will not cause the slightest discomfort to a healthy woman will cause excruciating pain to another woman who is under emotional stress during the menopausal stage. When we discover the clue to this hypersensitivity (which is probably due to a severe disturbance of the endocrine system) and its working mechanism, it will enable us in a great measure to control the burning mouth symptoms.

Cancerophobia that most often accompanies these syndromes is probably a result rather than a cause of the disease. Indeed, a nervous patient, after the age of 50 years, suffering from constant burning of the mouth would be likely to consider cancer as the cause. The fear of cancer tends to make the patient more and more melancholic and indirectly may aggravate the pre-existing local condition. In many instances, the onset of symptoms follows severe shocks of the central nervous system dealt by extraordinarily depressing events in the patient's emotional life.

TREATMENT

The treatment of burning mouth should be directed at all of the possibly etiologic factors.

1. All of the sources of local irritation and undue pressure by the dentures should be thoroughly eliminated.
2. Centric relation should be checked and double checked. A new centric occlusion that is in harmony with centric relation should be remounted on an adjustable articulator to correct occlusal disharmonies.
3. Border extension and stability of the dentures should be explored with utmost care.
4. Whenever indicated, hormones should be administered.
5. A balanced diet rich in vitamins and essential minerals should be prescribed.
6. Psychotherapy should be instituted in mild cases by the dentist and in severe cases by the psychiatrist.

In order for psychotherapy (even in mild cases of burning mouth) to be successful, the dentist must be fully acquainted with the past history of the patient and he must thoroughly understand the complications that may result from the environmental conditions in which the patient lives. No dentist should undertake or continue the treatment of burning mouth unless he is sure of the utmost confidence and cooperation of the patient. Reassurance is an important factor in the treatment of this disorder, and absolute confidence of the patient is imperative.

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136 East 54th St.
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REMOVABLE PARTIAL DENTURES

TREATMENT PLANNING FOR REMOVABLE PARTIAL DENTURES

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THE DENTIST IS RESPONSIBLE for the design of removable partial dentures. This is not, and should not be, the responsibility of the dental laboratory technician. The dental laboratory technician has the responsibility to his profession to demand a quality of leadership and competence from the dentist which he can respect and follow with confidence.

The prescription for technical fabrication of removable partial dentures by a dental laboratory should consist of completely designed diagnostic casts and written instructions. This article offers an orderly step by step procedure that the dentist may follow to provide an adequate design on diagnostic casts.

ARMAMENTARIUM

Certain materials are required to correctly design restorations on diagnostic casts. These are (1) a surveyor complete with a cast holder, an analyzing tool or stylus, and a carbon marker, (2) undercut gauges—0.010 inch, 0.020 inch, and 0.030 inch, (3) a red and blue† and a brown‡ crayon type pencil, and (4) a 4H or 5H lead pencil (Fig. 1).

COLOR CODE

Different colors are used on the diagnostic casts to indicate parts of the denture or procedures to be performed. The colors used are: (1) red—tooth surfaces to be ground, prepared, or recontoured, (2) blue—the acrylic resin denture base, (3) brown—the metal (framework or denture base), and (4) black—survey line and tissue undercuts.

Presented as an essay and table clinic before the American Academy of Restorative Dentistry, Chicago, Ill.

This article represents the personal viewpoint of the author and is not to be construed as a statement of official Air Force policy.

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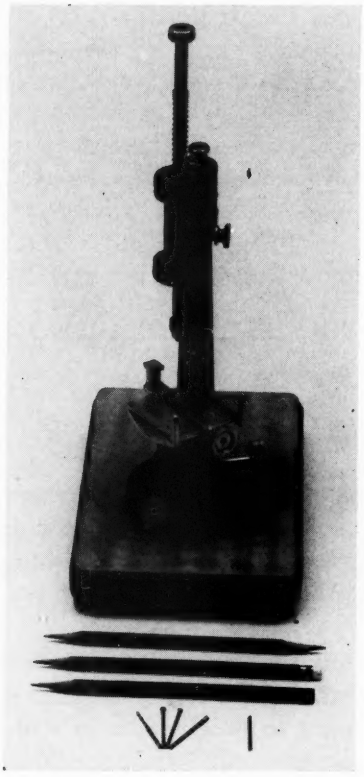

Fig. 1.—The armamentarium required to design removable partial dentures on diagnostic casts.

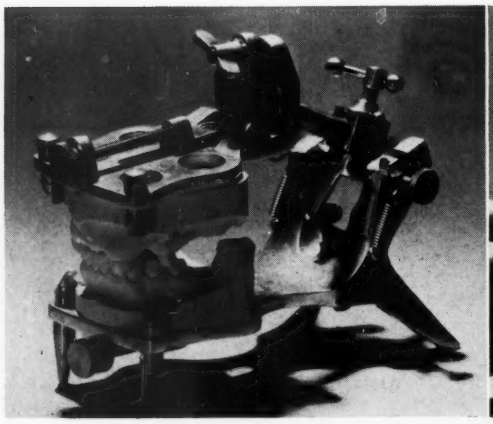

Fig. 2

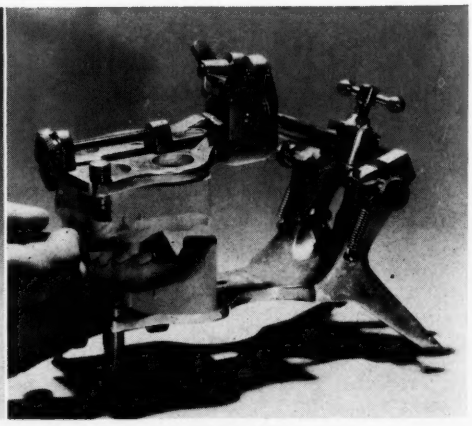

Fig. 3

Fig. 2.—The marks indicate the teeth that will require rest preparations.
Fig. 3.—The location of cuspal grinding to provide additional space for occlusal rests is indicated with red crayon pencil.

PRELIMINARY EXAMINATION OF DIAGNOSTIC CASTS

The diagnostic casts are mounted on an articulator and examined carefully. The rest preparations are located and indicated by a mark on the base portion of the diagnostic cast (Fig. 2). Adequate rest preparations are essential. The extent and location of cuspal reductions to provide additional space for occlusal rests are indicated in red crayon pencil (Fig. 3).

The lingual aspect of the occluded diagnostic casts is examined for adequate space on the maxillary anterior teeth for proposed lingual rests, indirect retainers, etc. A black lead pencil line is drawn on the lingual surface of the maxillary anterior

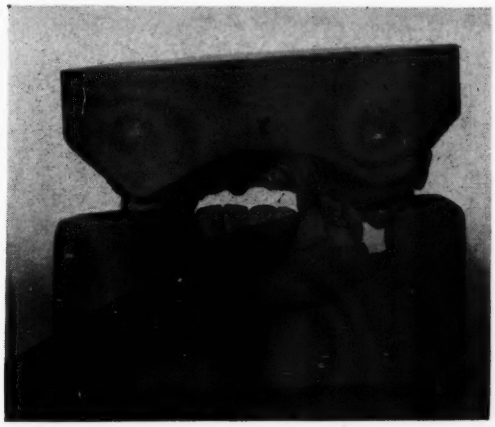

Fig. 4.—The occluded lower anterior teeth are used as a guide to draw a black lead pencil line on the lingual surface of the maxillary anterior teeth.

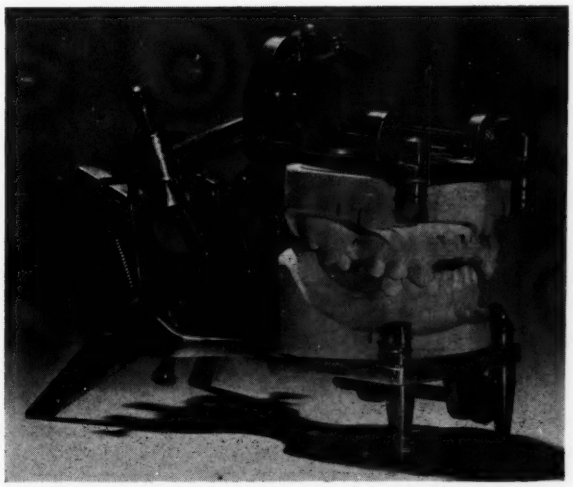

Fig. 5.—Tube teeth, facings, or metal pontics are indicated by a symbol on the diagnostic cast.

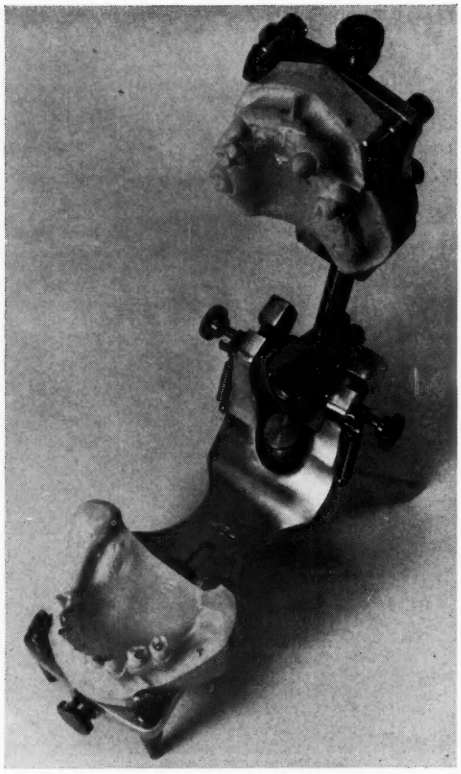

Fig. 6.—The location and extent of occlusal corrections and recontouring are indicated with red crayon pencil.

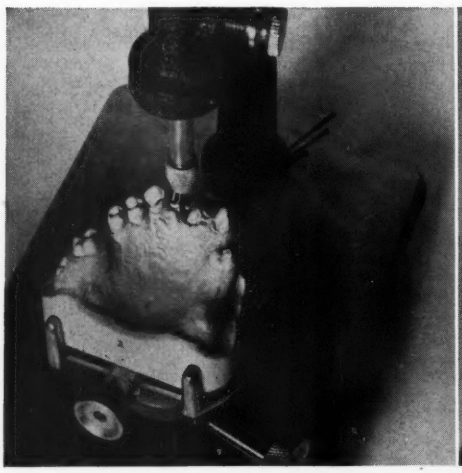

Fig. 7.

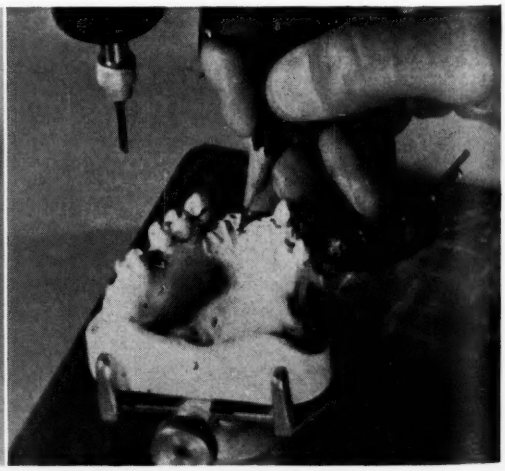

Fig. 8.

Fig. 7.—Three orientation or tripod marks are made on the maxillary diagnostic cast.
Fig. 8.—The tripod marks are crossed to pinpoint the position for orientation of the cast.

Fig. 9.

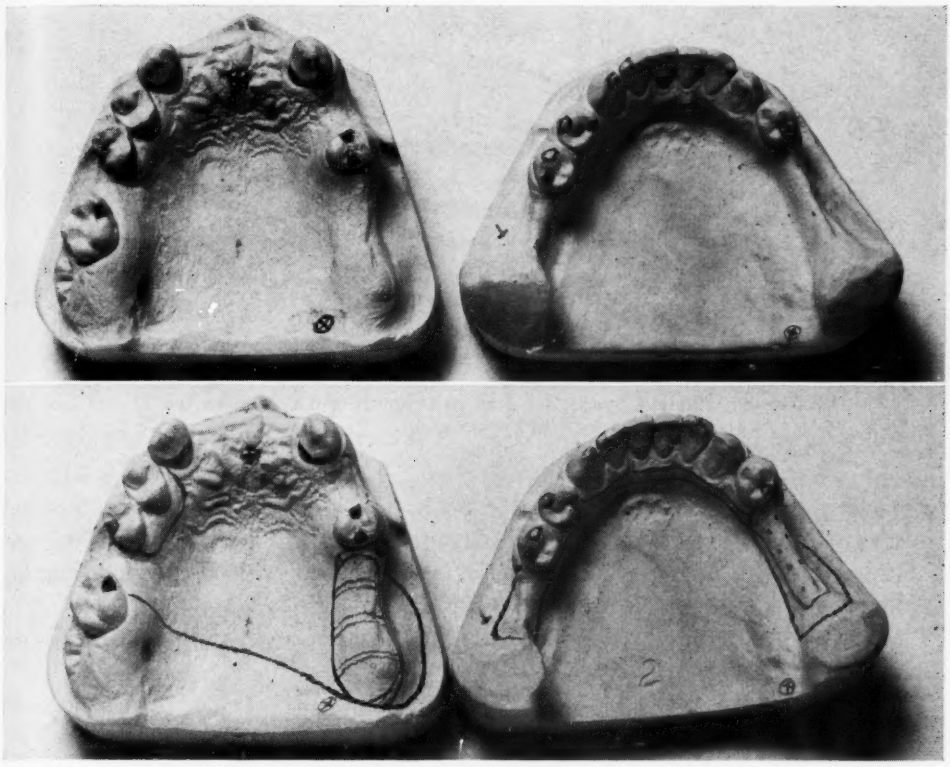

Fig. 10.

Fig. 9.—The rest preparations are drawn on the teeth with a red crayon pencil.
Fig. 10.—The metal denture base and framework design are outlined with brown crayon pencil. Acrylic resin denture bases are outlined with blue crayon pencil.

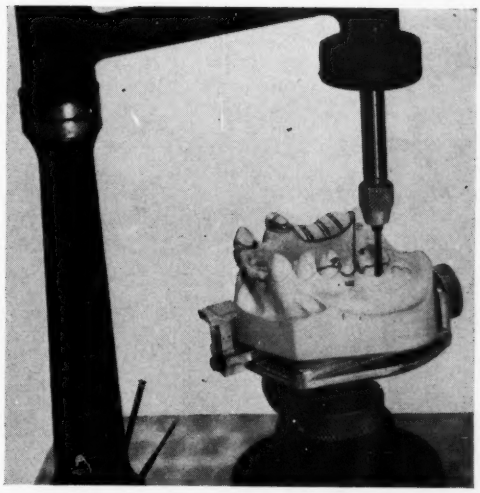

Fig. 11.—The survey line is drawn on the abutment teeth and other teeth that are involved in the restoration.

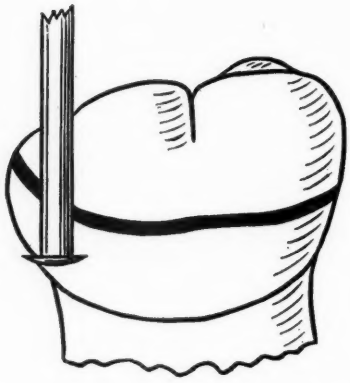

Fig. 12.—The selected undercut gauge is placed so it contacts the tooth at the survey line and in the undercut.

teeth using the occluded lower anterior teeth as a guide to indicate the gingival and incisal limits of anterior rests or indirect retainers (Fig. 4).

Tube teeth, facings, or metal pontics are indicated with a pencil, using the following symbols: *T*—tube teeth, *F*—facings, and *M*—metal pontics.

Each symbol is marked on the art portion of the cast adjacent to the area where it applies (Fig. 5).

ANALYZING THE DIAGNOSTIC CAST

The diagnostic cast is placed on a surveyor–cast holder at a level or horizontal tilt. The abutment teeth are examined with an analyzing tool to locate usable undercuts and to determine contour. If the teeth require recontouring, the location and extent are indicated with a red crayon pencil (Fig. 6). The most favorable tilt that will permit convenient and proper placement of clasps, minor connectors, anterior teeth, and denture bases is determined at this time.

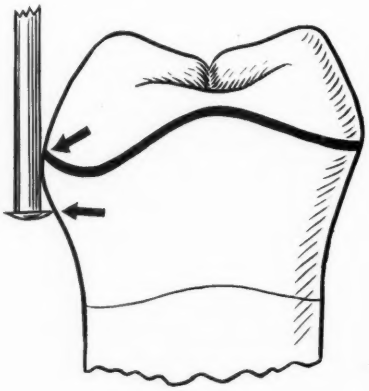

Fig. 13.—The undercut gauge is positioned so that the head and shank touch the tooth simultaneously.

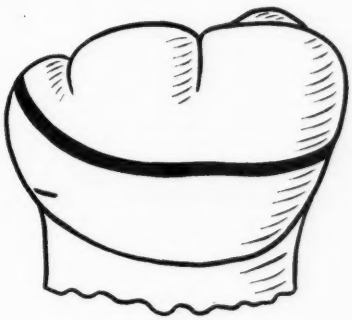

Fig. 14.—The location of the head of the undercut gauge is marked with a black lead pencil.

ORIENTATION OF THE DIAGNOSTIC CAST

Using the tip of the surveyor carbon marker, a position of the cast is located that will permit three widely separated points to be scribed. The surveyor is locked and these three positions are marked in the same plane of orientation (Fig. 7). The marks are crossed with a black lead pencil to pinpoint the position of orientation (Fig. 8). This procedure permits accurate reorientation of the cast on the cast holder by either the dentist or the dental laboratory technician.

DEVELOPING THE BASIC FRAMEWORK DESIGN

The diagnostic cast is removed from the cast holder for convenience. The rest preparations that are to be prepared in the mouth are drawn with a red crayon pencil (Fig. 9). Acrylic resin denture bases are outlined with blue and metal denture bases are outlined with brown crayon pencil. The metal framework design is drawn with a brown crayon pencil to harmonize and join the major connectors, indirect retainers, and minor connectors (Fig. 10).

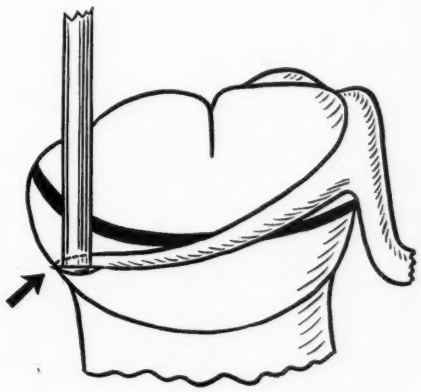

Fig. 15.—The mark shown in Fig. 14 represents the gingival edge of the clasp tip that will engage the undercut.

COMPLETING THE DESIGN

The diagnostic casts are remounted on the cast holder by use of the orientation or tripod marks. Survey lines are drawn on the abutment teeth and other teeth that will be involved in the restoration (Fig. 11).

The carbon marker in the surveyor is replaced with the indicated size of undercut gauge depending on the undercut condition, length, and size of the proposed clasp arm. As a general rule, with chrome-cobalt alloy castings, the 0.010 inch gauge will suffice for short clasp arms and the 0.020 inch gauge for long clasp arms. The 0.030 inch gauge is used for extremely long, wrought wire, flexible clasp arms. Gold alloy castings of the same dimension will accommodate slightly larger undercuts than chrome-cobalt alloy castings.

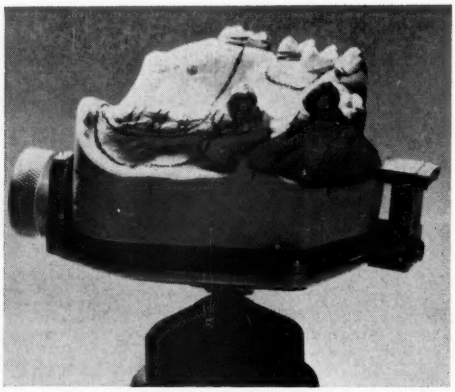

Fig. 16.—The clasp arm is drawn with a double line so that the occlusal and gingival parts will be indicated to the dental laboratory technician.

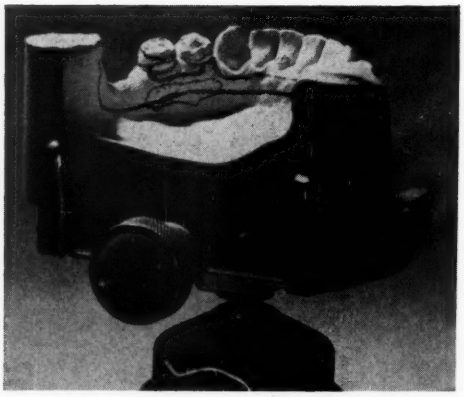

Fig. 17.—Undesirable soft tissue undercuts that may interfere with the insertion of the restoration are indicated.

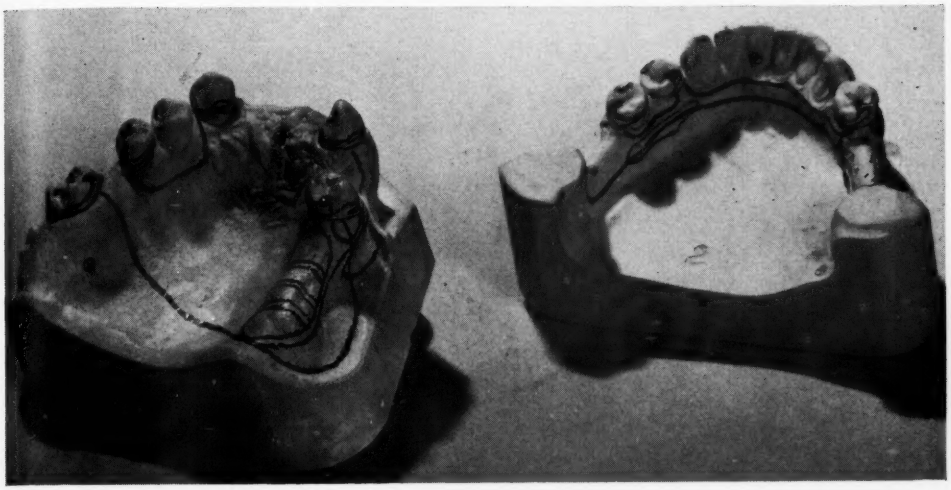

Fig. 18.—The designs are completed.

The selected gauge is placed on the undercut (Fig. 12) so that the head and the shank simultaneously touch the tooth (Fig. 13). This spot is marked with a pencil (Fig. 14), and it is verified with the head of the undercut gauge. The mark represents the gingival edge of the clasp tip that will engage the undercut (Fig. 15).

The clasp arms are drawn with brown crayon pencil, scribing a double line so that the occlusal and gingival parts will be indicated to the dental laboratory technician (Fig. 16). The clasp arms must conform with the position and location of the survey line and the depth of the undercut to be engaged by the clasp tip.

The position and extent of undesirable soft tissue undercuts that may interfere with the insertion of the restoration are indicated (Fig. 17). This completes the design of the restoration (Fig. 18).

SUMMARY

A step by step sequence for the design of removable partial denture diagnostic casts by the dentist has been presented.

CONCLUSIONS

1. Adequately designed diagnostic casts are an invaluable aid and guide in treatment planning.

2. Diagnostic casts designed by the dentist who initiates removable partial denture restorations constitute the best prescription for the dental laboratory.

3. Diagnostic casts serve as an excellent "blueprint" for the mouth preparation.

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THE SPRING-SLIDE JOINT FOR LOWER FREE END REMOVABLE PARTIAL DENTURES

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A GREAT DIFFERENCE exists between the ability of edentulous ridges and of the remaining teeth to support masticatory loads. Three factors are important: (1) the amount of the force, (2) the direction of the force, and (3) the displaceability of the bearing tissues as a result of the force.

A tooth with its periodontium is able to withstand relatively great forces when these are in an axial or approximately axial direction. However, lateral forces will soon cause pathologic conditions in the periodontal membrane. The residual ridge is not able to withstand as much force as the tooth, but there is no important difference with regard to the direction of the forces. Generally, a vertical direction is most favorable, but only because the forces are transported to the greatest area of the bearing tissue.

The resiliency of the residual ridge is much greater than that of a tooth, from 0.2 to 0.7 mm.[1] or from 0.2 to 1 mm.[2] during normal conditions. The resiliency of pathologic ridges is from 1 to 2 mm.[1]

MOVEMENTS DURING MASTICATION

Because of the resiliency of the residual ridge, the free end partial denture makes small movements during mastication. This mobility is limited because of the connection with the abutment teeth. Many dentists feel this mobility must not be totally prevented.[1,3-6] We subscribe to "the three freedoms" with regard to the mobility of the free end partial denture.[1,4,5] The denture can have the following small movements: vertical translation, rotation around a transverse axis, and rotation around a sagittal axis. If a vertical force is exerted on the middle of the denture base, it is moved slightly in a vertical direction and a vertical translation occurs. Rotation around a transverse axis occurs when forces are exerted at the distal end of the denture base (Fig. 1). Rotation around a sagittal axis is shown in Fig. 2. If one denture base is depressed, the other base on the same denture must take part in this movement and make a rotation around an axis situated in the jaw under it.

A fourth movement also occurs (Fig. 3). In the last phase of mastication, the lower teeth move into centric occlusion from a lateral position. When food is between the teeth, there is a pressure in the lower jaw in a verticobuccal direction and in the

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Read before the Scandinavian Dental Association, Copenhagen, Denmark.
Revised from the *Norwegian Dental Journal*, vol. 70, pp. 10-22, 1960.

upper jaw in a verticopalatal direction. If a free end partial denture is present in the lower jaw, the denture must be allowed to move slightly in a verticobuccal direction, depending on the resiliency of the alveolar ridge.

SPRING-SLIDE JOINT

Several types of removable partial dentures satisfy the requirements of mobility.[1,4-7] However, these requirements must also be combined with a favorable transmission of stresses from the denture to the abutment teeth. To solve these problems, a device called the "spring-slide joint" was developed.

Construction.—The spring-slide joint is a device for lower free end partial dentures which consists of (1) a stainless steel spring wire with its two ends fixed in the denture and (2) a clasp placed upon the abutment tooth (Fig. 4).

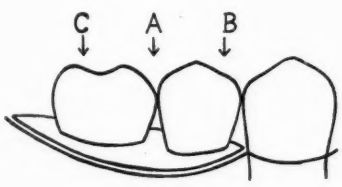


Fig. 1.

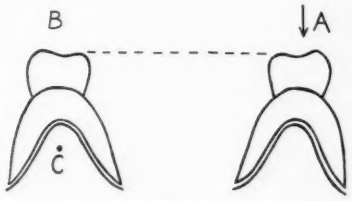


Fig. 2.

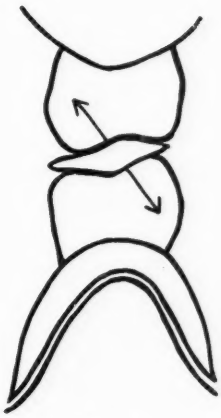


Fig. 3.

Fig. 1.—A vertical translation of the denture base occurs when the force is exerted in the middle of the base at *A*. Rotation around the transverse axis occurs when the force is at *B* or *C*. (From Norwegian D. J. 70:12, 1960.)

Fig. 2.—Rotation around a sagittal axis occurs in one denture base *(B)* when the denture base on the opposite side *(A)* is depressed. (From Norwegian D. J. 70:12, 1960.)

Fig. 3.—The lower denture moves in a verticobuccal direction during the last phase of mastication. (From Norwegian D. J. 70:13, 1960.)

The clasp has a channel or slideway for the middle part of the wire. This slideway crosses the clasp in a transverse direction and is 2 mm. long and high enough so that a wire of 0.8 mm. thickness can slide up and down easily. The inside of the slideway and the spring must be smooth so the friction between them is reduced to a minimum. The slideway must lie at the middle part of the distal surface of the tooth and make an angle of 45 to 60 degrees with the horizontal plane.

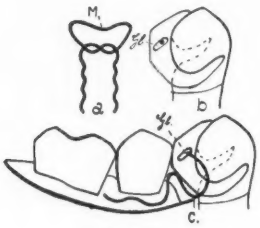
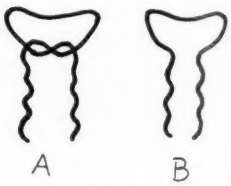


Fig. 4.



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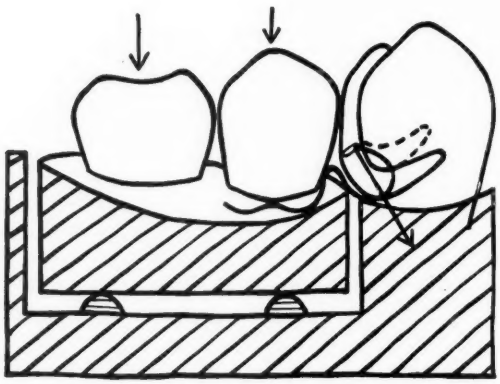

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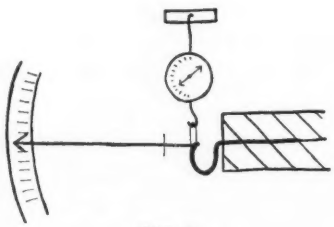


Fig. 7.

Fig. 4.—The spring-slide joint consists of a steel wire that passes from the denture base through a slideway in the body of the clasp and back into the denture base. (From Norwegian D. J. 70:14, 1960.)

Fig. 5.—*A*, The general form of the spring. *B*, The spring is formed so that it will transmit more stress to the tooth. (From Norwegian D. J. 70:15, 1960.)

Fig. 6.—A free end partial denture is on a plaster block model. The plaster block lies on four small rubber stops in a plaster box. When force is applied on the artificial teeth, the spring moves in the slideway as the rubber stops are displaced. (From Norwegian D. J. 70:15, 1960.)

Fig. 7.—The movements of the spring are measured by a lever which increases the magnitude fifteen times. (From Norwegian D. J. 70:16, 1960.)

The spring is made of a stainless steel wire with a diameter of 0.7 or 0.8 mm. The spring may be formed to transmit greater or less stress to the abutment tooth (Fig. 5). The middle part of the spring must lie close to the upper border of the slideway when there is no stress on the denture base. This position provides good retention for the denture and permits the spring to move down the slideway during mastication.

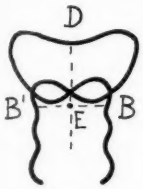
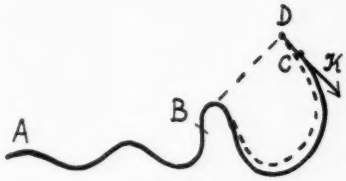


Fig. 8.



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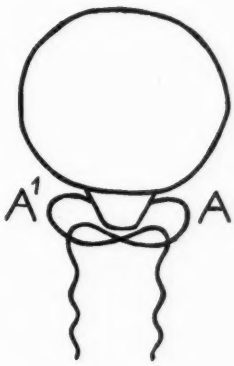

Fig. 10.

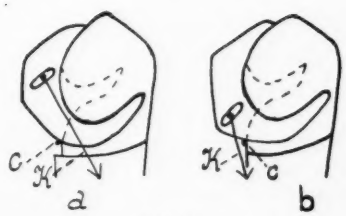

Fig. 11.

Fig. 8.—The direction of the pressure from the spring must be directed down the long axis of the abutment tooth. (From Norwegian D. J. 70:16, 1960.)

Fig. 9.—Seen from the side, the stress is directed by the spring downward and slightly mesially in relation to the root of the abutment tooth. (From Norwegian D. J. 70:16, 1960.)

Fig. 10.—The spring can make small movements in the direction of AA^1 or A^1A to avoid transmission of lateral stresses to the abutment tooth. (From Norwegian D. J. 70:17, 1960.)

Fig. 11.—*a*, The pressure of the spring must be directed over the lower border of the clasp. See point *C*. *b*, When the pressure of the spring is not directed over point *C*, the clasp is displaced from the tooth when stress is applied. (From Norwegian D. J. 70:18, 1960.)

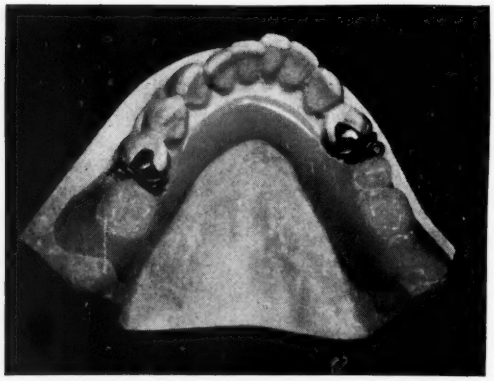

Fig. 12.—The lower left second bicuspid and lower right first bicuspid are used as abutment teeth. The clasps are placed on the natural crowns. Good masticatory function, normal soft tissue conditions, and no caries were observed after 11 months. (From Norwegian D. J. 70:19, 1960.)

SPRING-SLIDE JOINT FUNCTION

If a vertical force is exerted on the teeth of the denture, the denture base is pressed down according to the displaceability of the tissue. Then, the spring slides downward a little in the slideway and at the same time directs pressure against the floor of the slideway (Fig. 6). It is possible to find the approximate magnitude and direction of this pressure and also to dispose these factors as favorably as possible for the tooth.

An experiment is shown in Fig. 7. A spring is fixed with its two ends in a vise. The middle part of the spring is moved by a weight which shows the magnitude of force necessary to move the spring. The movements of the spring are measured

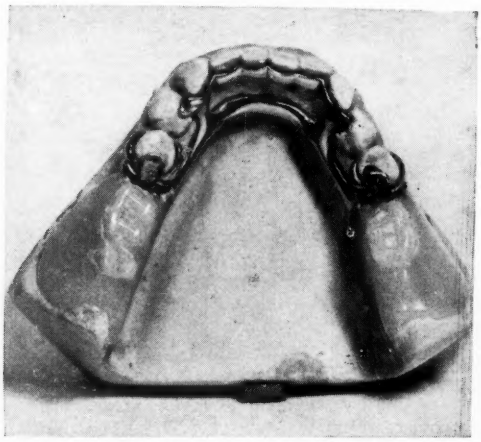

Fig. 13.—The lower second bicuspids are used as abutment teeth, with indirect retention on the anterior teeth. After 2 years, caries developed on the abutment teeth. The teeth were filled with silver amalgam, and the denture was seated when the amalgam was plastic to obtain a good adaptation of the clasps. (From Norwegian D. J. 70:19, 1960.)

by a lever which enlarges the movements fifteen times. In this way, the relationship between the movements and the pressure of different springs can be found. Influencing factors are the thickness of the wire and the form and length of the free part of the spring (Fig. 5).

The direction of the pressure exerted by the spring must be favorable for the tooth. The direction of the force, considered from above, must be down the long axis of the tooth. In Fig. 8, *B* and B^1 are the ends of the free part of the spring. The line BB^1 is divided in two equal parts by point *E*. *D* is the middle part of the spring in the slideway. The line *ED* indicates the direction of the pressure of the spring.

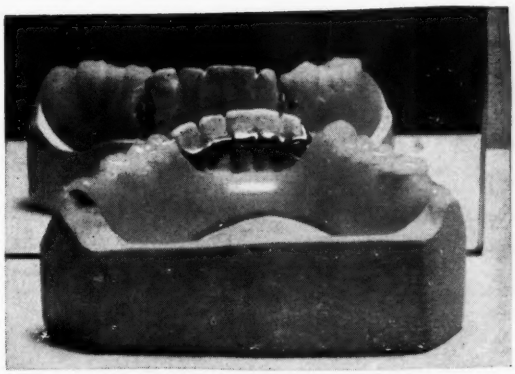

Fig. 14.—Only the four incisors and one cuspid remain. A continuous clasp was constructed with a slideway at both ends. The direction of insertion of this clasp is oblique, which gives sufficient retention to the denture. (From Norwegian D. J. 70:20, 1960.)

Fig. 9 shows the direction of the force seen from the buccal or lingual side. *AB* is the part of the spring fixed in the denture base. Point *C* is the middle part of the spring when the denture base is at rest on the tissue (without external force), and *D* is the same part when the spring is in action. *D* creates pressure against *C*, and the direction of the pressure is *DC* or a perpendicular to the line *BD*. In situ, this pressure will be directed downward and slightly mesially against the middle part of the root (Fig. 6). This direction of force is favorable for the tooth. A slight pressure will be exerted on the tooth in a mesial direction, but this pressure is transmitted to the other remaining teeth and no damage will be done. The same pressure is transmitted to the denture in a distal direction, but the form of the alveolar ridge (ascending ramus) provides sufficient resistance against pressure in this direction.

In the upper jaw, there is no natural barrier against pressure of the denture base in a distal direction. Therefore, the spring-slide joint is not used in the upper jaw.

The spring must be allowed short movements in a lateral direction in the slideway to avoid transmission of lateral stresses from the denture to the abutment tooth (Fig. 10). Also, the pressure of the spring must be directed over the lower border of the clasp, or the clasp will be displaced from the tooth (Fig. 11).

Generally, no relining of the denture base will be necessary. After some years, however, it will be seen in some patients that the rest position of the spring is

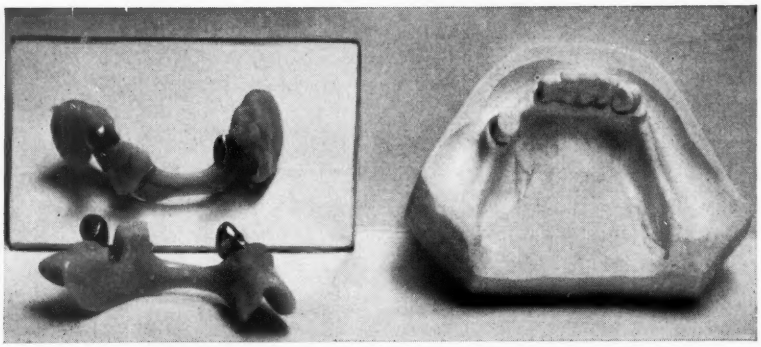

Fig. 15.

Fig. 16.

Figs. 15 and 16.—A double Carmichael crown is located on the lower right cuspid, with a slideway in the upper crown. A small open slideway is used with a fixed partial denture at the distal side of the lower left lateral incisor near the gingival margin. This slideway contains a spring wire whose ends are fixed at the inside of the denture. The lower second bicuspid is supplied with a telescopic crown. The upper crown contains the slideway. (From Norwegian D. J. 70:20, 1960.)

changed a little. It is no longer close to the upper border of the slideway. This is because of the slight setting of the denture. In such cases, the spring must be bent a little to restore the correct rest position.

Figs. 12 through 16 illustrate practical uses of the spring-slide joint in lower removable partial dentures.

SUMMARY

The spring-slide joint is a means of stress breaking for lower free end partial dentures. The joint consists of a spring wire which is fastened with its ends in the acrylic resin denture base and a clasp with a channel for the wire. The connection is loose and permits the denture different degrees of movement. The joint permits favorable transmission of stresses from the denture base to the abutment teeth. Dentures with spring-slide joints permit good mastication and are well tolerated by the patients.

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PERIODONTAL PROSTHESIS

USE OF RUBBER-BASE MATERIALS IN PERIODONTAL PROSTHESIS

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PERIODONTAL PROSTHESIS is a therapy that deals with occlusal traumatic factors. The extent of this rehabilitation is usually dictated by the mobility of the teeth after *all* other therapy (marginal and occlusal) has been attempted. The prosthesis may be removable or fixed.

The removable prostheses include the night guard,[1] the continuous clasp splint, and the prosthesis with precision attachments.[2] The fixed prostheses include wire and acrylic resin,[3] pin and acrylic resin,* and full coverage cast splints. This article will discuss only the full coverage cast splints.

FIXED PERIODONTAL PROSTHESIS

It is important to differentiate between a fixed partial denture and a fixed periodontal prosthesis. A fixed partial denture replaces one or more missing teeth, whereas a fixed periodontal prosthesis stabilizes a segment or a full dental arch of teeth against deleterious forces. Often, as in the presence of an unbreakable oral neurosis, removable periodontal splints (night guards) are used in conjunction with fixed periodontal splints (Fig. 1). The removable splints are worn during the night to help dissipate traumatic stresses generated by the oral neurosis.

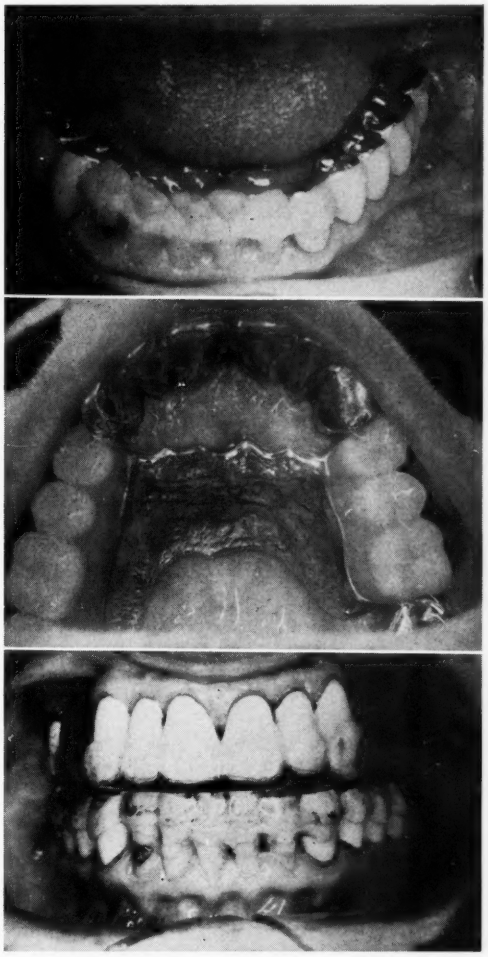
RUBBER-BASE IMPRESSION MATERIALS

Rubber-base impression materials are used for the construction of cast, full coverage periodontal splints. The material is accurate[4,5] and the armamentarium is simple. Rubber-base impression material is especially suitable for a full or quadrant dental arch impression technique[6] because of its strength, ability to register undercuts without distortion, and sufficient working time. Furthermore, the restorations may be completed on the master casts.

MOUTH PREPARATION FOR PERIODONTAL PROSTHESIS

Deflective occlusal contacts (prematurities) in centric relation must be eliminated. The grinding procedures should provide holding contacts in centric occlusion.[7] However, these contacts should permit freedom for deviation in closure

*G. Kramer: Personal communication.



A.

B.

C.

Fig. 1.—*A* and *B*, The occlusal surfaces after complete rehabilitation. *C*, The upper and lower night guards are in place. The patient wears the guards during the night to offset traumatic stresses. The night guards are balanced for all functional positions.

resulting from altered neuromuscular reflexes. This may be termed "centric occlusal freedom." The extent of this freedom should be 1 mm.,* and it is provided by modifying cusps.

Although not all occlusal planes need alteration before periodontal occlusal rehabilitation,[8] extreme malalignment must be eliminated. The establishment of an occlusal plane is often facilitated by the use of fixed or removable temporary restorations. The cuspal form of these restorations must be integrated with the established occlusion. Group function should be established where possible. Balancing side interferences must be eliminated. Tooth preparation is confined to one quadrant at a time to maintain the correct vertical dimension of occlusion.

*H. M. Goldman: Personal communication.

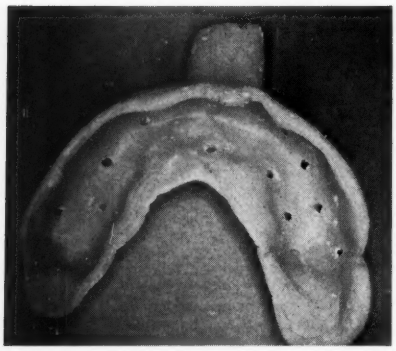
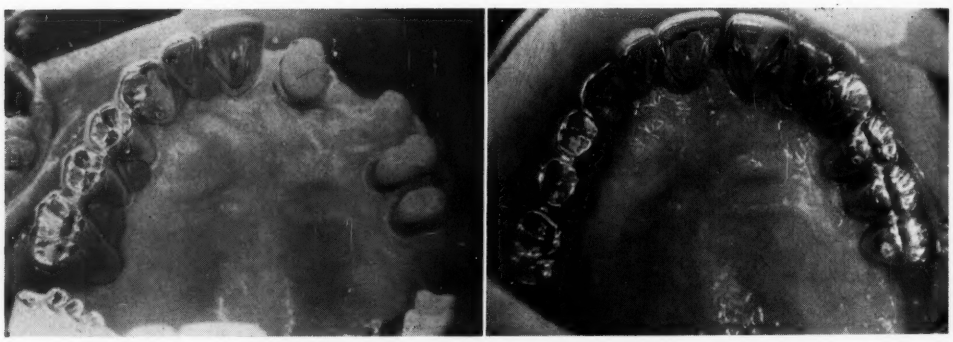


Fig. 2.—An impression tray is made from cold-curing acrylic resin. Retention for the impression material is obtained by holes or by the use of a rubber adhesive.



A. *B.*

Fig. 3.—*A*, The tissue around the prepared abutments is retracted with string in the sulci. The embrasures are blocked out with modeling clay to facilitate removal of the master impression. *B*, The completed periodontal splint is in the mouth.

With full dental arch impressions, the periodontal prosthesis can be integrated with established relationships. Centric occlusal freedom, the occlusal plane, and balanced occlusion can be incorporated into a restoration which will help stabilize the dentition and require minimal adjustments in the mouth.

As a result of the mouth preparation, a semi-adjustable articulator, such as the Hanau model H, can be used. A hinge axis articulator is not necessary and is often detrimental because no allowance is made for centric occlusal freedom.

IMPRESSION TECHNIQUE

An alginate (irreversible hydrocolloid) impression is made of the dental arch for the periodontal splint and is poured in artificial stone. An interocclusal wax centric relation record is made of the segment to be prepared in a special tray. The record is stored and utilized for the construction of a temporary acrylic resin fixed partial denture.

The abutment teeth are prepared, and an acrylic resin tray is constructed on the preliminary cast (Fig. 2). One layer of baseplate wax is adapted over the outline form of the tray on the cast, except on the stops and the abutment teeth, to obtain a uniform thickness of rubber-base material in the impression.

After the abutment teeth are prepared, the gingival tissue is retracted with a chemically impregnated commercial string (Fig. 3). A 10 per cent solution of trichloracetic acid is used to control hemorrhage (Fig. 4). The string is kept in place for approximately 3 minutes. The tissue must be kept dry.

At the end of the retraction period, the dentist mixes the soft-bodied rubber-base impression material and loads the syringe while the assistant mixes the heavy-bodied material (Fig. 5). The string is removed, the contents of the syringe is injected into the sulci, and the entire abutment region is covered. During this period, the heavy-bodied mix has set sufficiently to be loaded into the resin tray. The tray

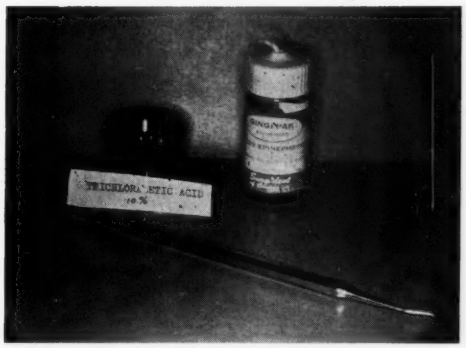
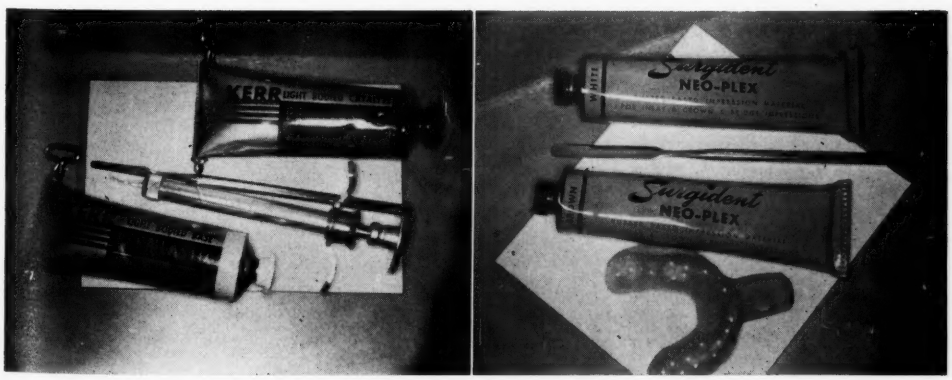


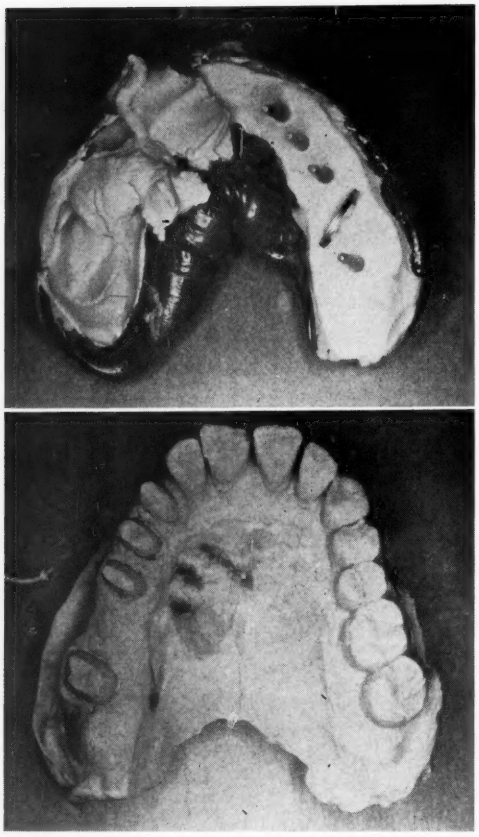
Fig. 4.—The retraction kit is used to hold the tissue away from the preparations and to control hemorrhage.



A. *B.*

Fig. 5.—*A*, The armamentarium for the initial soft-bodied mix. *B*, The armamentarium for the heavy-bodied mix.

A.



B.

Fig. 6.—*A,* The impression is poured in die stone, with dowels inserted into the abutment sites. Note the indelible pencil marks to help orient the position of the dowels. Note also the use of staples and the excess die material to facilitate retention for the second half of the master cast, to be poured in stone. *B,* The master cast. Water glass is used as the separating medium on the die area.

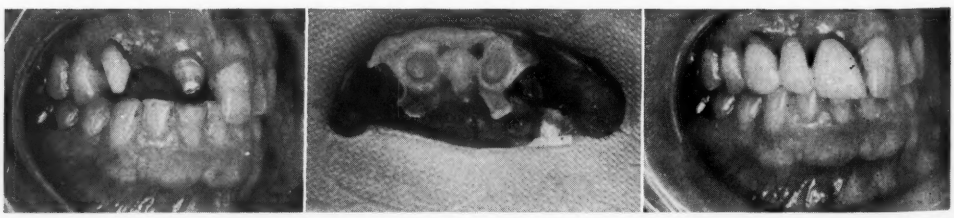
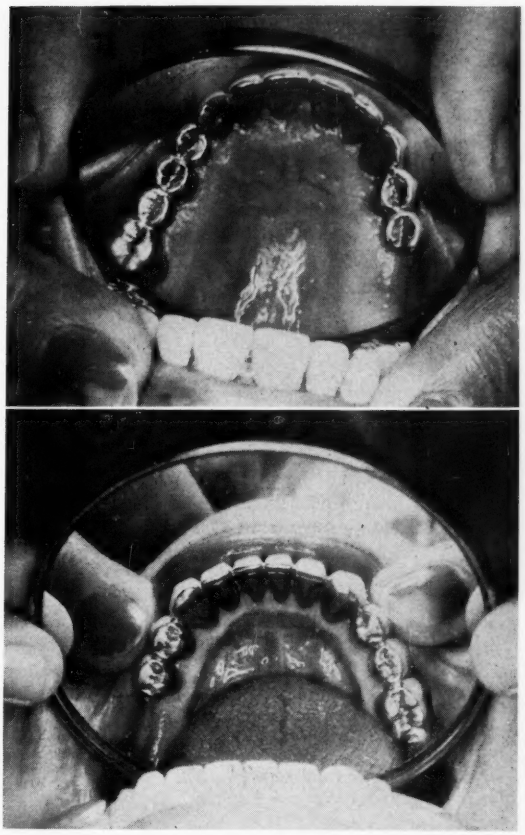


Fig. 7. Fig. 8. Fig. 9.

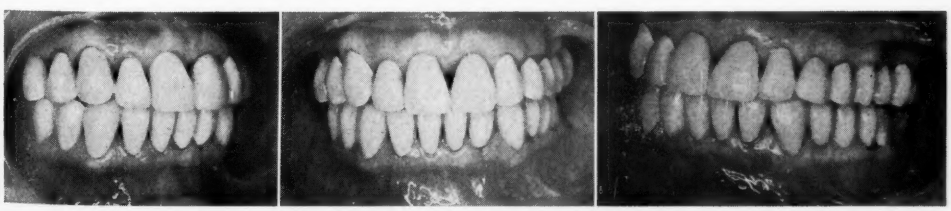
Fig. 7.—Two abutment teeth are prepared.
Fig. 8.—The cold-curing acrylic resin is setting in the wax record.
Fig. 9.—The completed temporary acrylic resin fixed partial denture is cemented in the mouth. Note that physiologic form is incorporated in it.

A.



B.

Fig. 10.—*A* and *B*, The completed periodontal protheses in place in the mouth.



A. *B.* *C.*

Fig. 11.—*A*, *B*, and *C*, The completed periodontal prostheses are in place in the mouth. Note that bicuspid occlusion on the right side is sufficient.

is placed in the mouth, seated with maximum pressure, and held in position for 3 minutes. The pressure on the tray is released, and the tray is left in the mouth for an additional 7 minutes to minimize distortion. The patient is instructed not to contact the tray with the teeth during this period. The tray is removed gently and examined for defects. If acceptable, the impression is poured in die stone and dowels are inserted (Fig. 6).

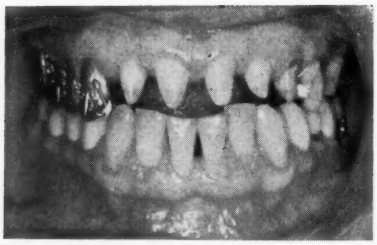


Fig. 12.—The framework of the posterior segment is in position, and the anterior abutment teeth have been prepared.

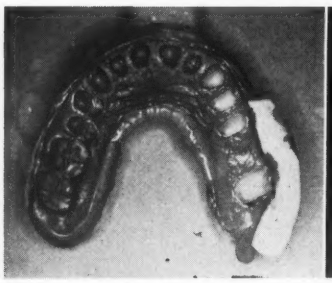


Fig. 13.

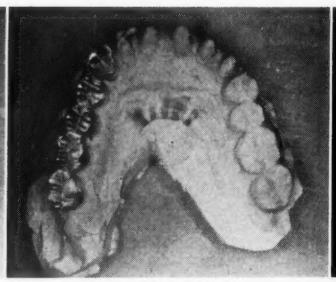


Fig. 14.

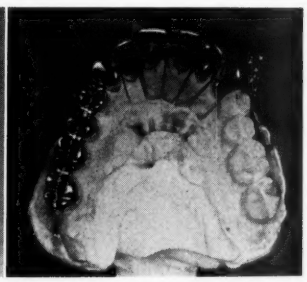


Fig. 15.

Fig. 13.—The impression containing the posterior framework is accurately related to the remainder of the dental arch.

Fig. 14.—The master cast is poured in artificial stone.

Fig. 15.—The anterior and posterior segments are combined as a one piece framework.

Fig. 16.—The one piece framework is accurately related in the mouth. The full dental arch framework is completed by the preparation of the remaining segment of abutment teeth utilizing the same procedure.

An impression of the opposing dental arch is made in irreversible hydrocolloid impression material, and the cast is poured in artificial stone. An interocclusal centric relation record and a conventional face-bow registration are made.

The wax interocclusal record made previously is employed in the construction of the temporary acrylic resin fixed partial denture (Figs. 7 through 9). The completed splint is tried in the mouth, and, after the necessary adjustments are made, it is cemented in place.

SUMMARY

A technique for construction of periodontal splints using rubber-base impression materials has been described. When adequate mouth preparations have been instituted, the advantages of the technique are: (1) periodontal splints are accurately related to the remainder of the dentition (Figs. 10 and 11), (2) a fabricated framework can be related to other abutment teeth by virtue of the strength of the material, thus eliminating the use of plaster and a subsequent appointment (Figs. 12 through 16), (3) the armamentarium is minimal, (4) the technique is simple, and (5) the procedures require a minimum of time and effort.

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FIXED PARTIAL DENTURES

A CONSERVATIVE ABUTMENT RESTORATION FOR ANTERIOR FIXED PARTIAL DENTURES

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EVERY ABUTMENT RESTORATION POSSIBILITY should be considered to determine which type best serves the needs of the patient. Each type of restoration possesses some merit, and each one constitutes a special tool which *may* solve the problem at hand.

One of the possible abutment restorations is the pinledge crown. When it is used with discretion and when the tooth preparation and crown fabrication are handled properly, a crown with excellent retention, maximum conservation of sound tooth structure, and delightful esthetic possibilities is available.

This article discusses the uses of this versatile abutment restoration and describes a simple technique for its construction.

FIXED PARTIAL DENTURE RETAINERS

A thorough knowledge of all types of retainers is necessary. Those commonly used in fixed partial denture prostheses will be considered.

Gold Inlay.—The gold inlay is an intracoronal retainer. While usually used for posterior fixed partial dentures, the gold inlay is occasionally used to provide an anterior lug rest seat. Its use for fixed partial denture support must be carefully considered.

Partial Veneer Crowns.—The three-quarter and pinledge crowns are extracoronal retainers.

Full Veneer Crown.—The full veneer crown is an extracoronal retainer. This abutment restoration in anterior fixed partial dentures allows for the use of a "window" in which acrylic resin or porcelain can be placed for esthetic appearance.

FACTORS IN DIAGNOSIS

The following factors must be analyzed when the patient needs an anterior fixed partial denture: (1) the length of the edentulous space, (2) the stresses which will be directed against the restoration, (3) the caries susceptibility of the patient,

(4) the presence of previously placed restorations in the abutment teeth, (5) the esthetic requirements, and (6) the previous dental experience of the patient with regard to fixed or removable dentures.

PINLEDGE CROWNS

Indications.—The pinledge crown is indicated for all upper and lower anterior abutment teeth which fulfill the certain requirements which follow: (1) the abutment teeth must be relatively noncarious, in a mouth with adequate oral hygiene, (2) the edentulous space must not be longer than the length of two pontics unless multiple terminal abutments are used (the distal restoration of the multiple abutment may be a pinledge crown), and (3) the abutment teeth must be mature and have small pulp chambers.

Pinledge crowns are useful also in the following situations: (1) on abutment teeth which are short gingivoincisally, which can provide little frictional retention, and on which the typical long, tapering preparation is impossible, (2) on cone-

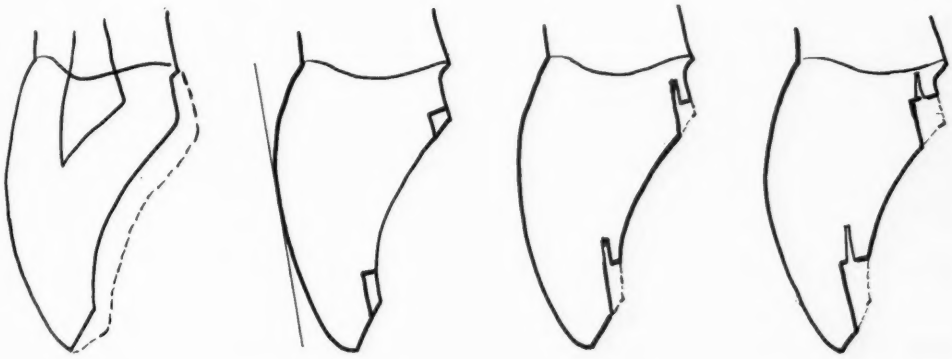

Fig. 1. Fig. 2. Fig. 3. Fig. 4.

Fig. 1.—The gross tooth reduction is completed, and the preparation is smoothed with finishing disks.
Fig. 2.—The ledges are created with a No. 702 carbide bur.
Fig. 3.—The pinholes are placed to a depth of 2 to 3 mm.
Fig. 4.—The ledges are enlarged labially to center the pinholes.

shaped cuspids with which parallelism of slices and grooves is difficult to obtain, (3) on bell-shaped teeth with which excessive tooth reduction for a three-quarter crown would be required to parallel the proximal surfaces, (4) with the end restoration when the terminal retainers consist of two restorations soldered together, and (5) on small lower anterior teeth which are difficult to prepare.

Contraindications.—It is advisable to avoid pinledge crowns when (1) the teeth are susceptible to caries, (2) there are restorations existing in the abutment tooth which cannot be included in the outline form of the proposed pinledge crown, (3) the edentulous space is too long, and (4) there is poor oral hygiene.

Advantages.—There are many advantages in using the pinledge crown as a fixed partial denture retainer.

1. The retention of the pinledge crown rivals that of the tightest fitting extracoronal retainers used on anterior teeth. Retention is achieved solely by the use of three parallel pins.

2. When properly constructed, the pinledge crown fulfills the requirements for support and strength. The fixed partial denture is supported by a sufficient bulk of gold on the lingual and proximal surfaces, where it is reinforced by definite ledges in the preparation.

3. The technique is simple and quickly executed.

4. Esthetic appearance is maintained by removing tooth structure from surfaces which are not exposed and where gold will not show.

5. The conservation of tooth structure in making the preparation results in little trauma to the pulp.

6. All margins are easily accessible for accurate finishing of wax patterns and of castings. The marginal fit is the key to the success of any restoration, and it is obtained with little difficulty in this procedure.

7. The direct wax pattern technique saves laboratory time and expense and assures accuracy of fit by eliminating possible errors in die fabrication.

8. Good oral hygiene is easily maintained around the abutment restoration.

Disadvantages.—There are two distinct disadvantages to the pinledge crown: (1) the dislike on the part of some dentists for waxing patterns directly in the mouth and (2) the lack of universal application of the crown dies for use on all anterior fixed partial dentures.

TECHNIQUE FOR ABUTMENT PREPARATION

The margins of the proposed abutment preparation are outlined on the tooth with a sharp pencil. This outline aids in limiting the cutting to the proper extent.

Fig. 5.

Fig. 6.

Fig. 5.—A fixed partial denture supplies the central incisors. Note the minimum display of gold on the lateral incisor abutment teeth.

Fig. 6.—A lingual view of the fixed partial denture seen in Fig. 5.

Fig. 7.

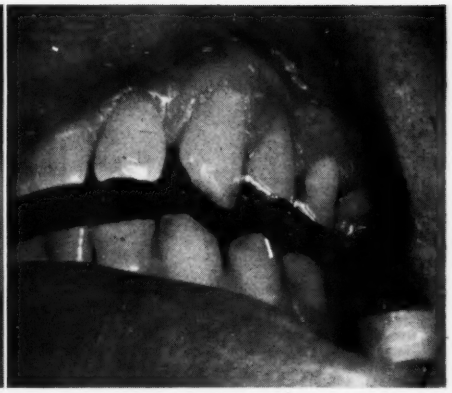

Fig. 8.

Fig. 7.—A lower cuspid is used as a cantilever abutment.
Fig. 8.—An upper cuspid is used as the anterior abutment for a short posterior fixed partial denture. Appearance would be poor if a three-quarter crown had been used.

The initial cut is made on the proximal surface next to the edentulous space using a 7/8 inch diamond disk. A slice is made that extends to or slightly below the free margin of the gingiva and labially to the margin that was outlined in pencil. Parallelism between the preparations in the abutment teeth must be considered when the slice is made. A definite finish line should be present at the gingival margin of the preparation when the slice is completed.

A small, knife edge diamond wheel is used to cut a definite finish line along the marginal ridge of the unsliced proximal surface as previously outlined. The cut should be of sufficient depth to create a stop for further lingual reduction and may be carried to the incisal edge and as far gingivally as possible.

The incisal bevel and lingual reduction are carried out with a large square edge diamond wheel. The incisal bevel should not extend labially past the pencil mark. The lingual cutting should reduce the tooth for clearance of the opposing teeth and must permit sufficient bulk to be used in the casting. The previous axial knife edge cut along the marginal ridge marks the limits of the lingual part of the casting, and no reduction should be necessary beyond this cut.

The cingulum is reduced with a tapered, diamond, cylindric stone. The stone is held so that the cingulum is cut parallel to the plane of the middle third of the labial surface. An appearance of slight undercutting results.

The same mounted cylindric stone is brought around to the proximal slice for further reduction, leaving a small part of the slice on the labial area untouched. The proximal reduction permits space for sufficient gold, which increases the strength of the abutment.

After the gross tooth reduction is completed, the marginal outline must have a definite finish line. The preparation is smoothed with finishing disks (Fig. 1).

A No. 702 carbide bur is used in a contra-angle handpiece to produce definite ledges. These ledges are placed in the proximal surface of the pontic side as a heavy groove ending near the gingival margin, in the cingulum, and in the lingual

surface just incisal to the middle third near the marginal ridge finish line of the preparation. The bur is held parallel to the middle third plane of the *labial* surface, and the three cuts are made quickly without changing the alignment of the bur. The ledges should be at least as wide labiolingually as the diameter of the bur. Little apical pressure is exerted during the cutting (Fig. 2).

The anterior walls of the ledges, having been cut parallel to each other, serve as guides for the placement of pinholes. By holding the shank of a No. ½ round bur against the anterior wall of the ledge, a hole is made 2 to 3 mm. in depth. There should be no lateral movement of the bur.

A No. 700 tapered, cross-cut fissure bur is used to define the pinhole (Fig. 3). The No. 700 bur is held against the anterior wall of the ledge and inserted in the hole made by the No. ½ round bur and quickly withdrawn. Once again, *no*

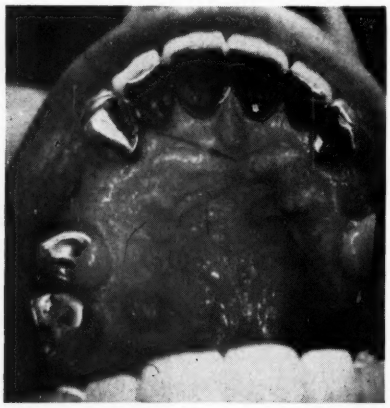

Fig. 9.—A six unit splinted fixed partial denture supplies two lateral incisors as pontics. The cuspids have pinledge retainers.

lateral pressure is exerted. Preformed plastic pins fit the hole made by a No. 700 bur precisely, and if the hole is enlarged laterally, the retentive quality of the pin is lost.

The ledges are enlarged with a tapered, diamond, cylindric stone which is at least as large as a No. 702 bur. The enlargement is made in a labial direction to center the pinholes in the ledge floors (Fig. 4). Apical pressure is avoided so that the pinholes will not be shortened and valuable retention lost (Fig. 5).

WAXING THE PATTERN

The prepared tooth is lubricated, with special attention given the pinholes. A softened piece of 30 gauge casting wax is burnished against the prepared surfaces and ledges and trimmed approximately to the margins of the preparation.

The pinholes are located by punching holes through the wax. Then, the plastic pins* are inserted in the holes and carefully pushed to place with an amalgam plug-

*Williams Gold Refining Co., Inc., Buffalo, N. Y.

ger. As each pin is inserted, blue inlay wax is flowed into the ledges and around the pin. The length of the pin is not shortened for clearance of occlusion.

Blue inlay wax is flowed over the entire preparation, and the adaptation of the wax to the margins is perfected. No matrix is used, no attempt is made to produce an anatomic carving, and the correct occlusion is not established at this time. These adjustments are made in the gold casting. A sufficient bulk of wax must exist so that the pins will be withdrawn in the pattern.

To protect the tooth until the casting is completed, the prepared tooth is sedated by placing paper points moistened with eugenol in each pinhole, and the paper points are sealed in the pinholes with zinc oxide and eugenol cement placed in the ledges. The teeth are usually comfortable after such treatment.

The usual investing and casting procedures are used to complete the restorations (Figs. 6 through 9).

MODIFICATIONS

Modifications which may be incorporated into the pinledge preparation are: (1) the use of a groove and two pins, (2) limitation of the reduction of the lingual surface so it does not include the incisal edge, (3) the use of a three-quarter crown preparation with a cingulum pin, and (4) the use of a three-quarter crown preparation without grooves and with a triangular pin arrangement on the lingual surface.

SUMMARY

The versatility, soundness, and simplicity of the pinledge crown procedure has been discussed. This technique develops casting strength, support, and a high degree of retention. When the technique is mastered and applied carefully, the pinledge crown has a definite place in fixed partial denture prosthesis.

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OCCLUSAL RECONSTRUCTION USING TRANSITIONAL CROWNS

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A TRANSITIONAL CROWN is a preliminary or working crown constructed on a die and made of a material permitting alteration or addition. The term "transitional crown" is employed to distinguish this type of crown from such devices as copings,[1] transfers[2] (transfer crowns and transfer inlays), and counterdies.[3]

Copings and transfers are not used as working or preliminary crowns but as means to seat dies correctly in the plaster impression. Their use is limited to that one function. A transitional crown has other uses as well.

A transitional crown is similar to a counterdie in its method of construction. The counterdie[4] was used originally in the preparation of swaged crowns and was generally made of a low-fusing metal in the form of a negative of the die. The counterdie did not take the approximate shape of the finished crown but the form of a sleeve closed at one end. This die negative or sleeve was placed over the crown metal and hammered down over the die until the crown metal was closely adapted to the die and of proper shape for use in the mouth.

The transitional crown is a valuable device in occlusal reconstruction and fixed prosthesis. There is almost no step wherein the transitional crown may not play its part.

RESIN TRANSITIONAL CROWNS

Transitional crowns are constructed of cold-curing acrylic resin on the final die of the prepared tooth, usually a full crown preparation. The resin has the advantage of easy alteration. Its fit can be improved if use has damaged it so that it does not offer a firm seat for the die. The length of the crown can be increased when it is short of contact with opposing teeth, and the labial and mesiodistal bulk can be increased or decreased when esthetic alignment is being determined. The crown can be made in the correct color and can be used as a temporary crown. Its occlusal surface can be adapted to the opposing teeth and firmly fixed for registering centric occlusion. The crown is easily ground and shows the markings of articulating paper plainly.

Fabrication.—It is almost impossible to prepare a tooth without at least minute scoring, caused by the finest of sandpaper disks. This scoring may make it impossible to remove the resin transitional crown when it is fully set. Therefore, the amalgam or copper die must be coated with a thin layer of wax before applying the resin. Then, the die is beaded with baseplate wax around the finish line. A matrix of 28 gauge casting wax is formed around the die and sealed to the wax

bead at the gingival margin. The beading supplies the space for the necessary bulk and prevents the resin from entering undercuts on the die stem. Acrylic resin liquid and powder are then alternately placed in the matrix until it is completely filled. When the resin has set, the wax matrix is removed and the crown is shaped and polished but with excess all over (Fig. 1).

METAL TRANSITIONAL CROWNS

Transitional crowns may be made of low-fusing metal (Melotte's metal).[4] This metal is an alloy of bismuth (50 per cent), lead (31.2 per cent), and tin (18.8

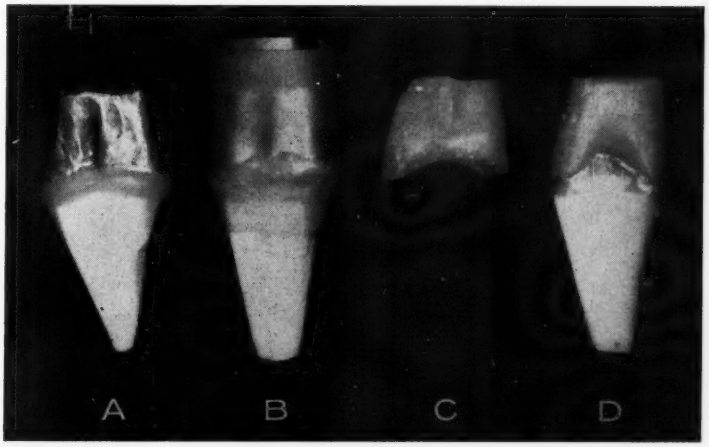

Fig. 1.—*A*, The copper-plated die is coated with a thin layer of wax and beaded at the finishing line. *B*, A sleeve of 28 gauge baseplate wax is attached to the die stem. *C*, The acrylic resin transitional crown is completed. *D*, The transitional crown is seated on the die.

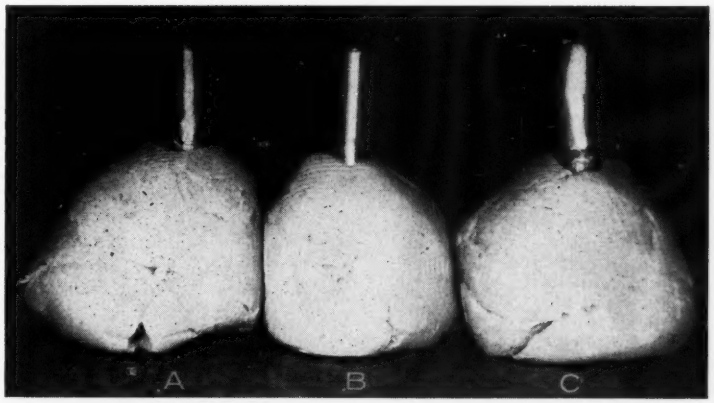

Fig. 2.—*A*, The die is embedded in Mouldine up to the finishing line. *B*, A copper band is placed over the die and embedded in Mouldine. The band is large enough to supply 1.5 mm. of bulk in the finished crown. *C*, The completed low-fusing metal transitional crown is trimmed and polished.

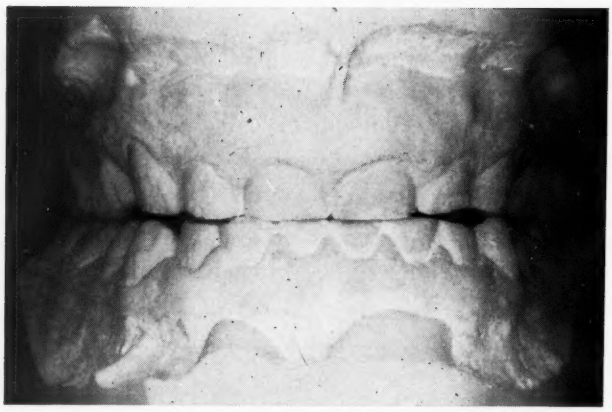

Fig. 3.—Extreme attrition of the incisors makes the use of acrylic resin or low-fusing metal transitional crowns unsuitable.

per cent). However, the metal crown is not easily altered once it is made, and it does not show the markings of articulating paper as well as an acrylic resin crown. The metal crown is not as easily ground as a resin crown, and the grindings are disagreeable to both the dentist and the patient. These metal crowns cannot be easily readapted to the prepared tooth or die if they are damaged. Their color is not good and their length cannot be increased readily. However, when the tooth preparations are small, low-fusing metal transitional crowns offer a more positive seat for both the tooth and the die.

Fabrication.—The amalgam or copper-plated die is inserted upright in Mouldine. The Mouldine is built up to form a shoulder around the finish line of the preparation. This shoulder will prevent the molten metal from flowing into undercuts in the die stem. The die is coated with a varnish and then "frosted" with a saturated solution of whiting in water by means of a brush or cotton pellet.

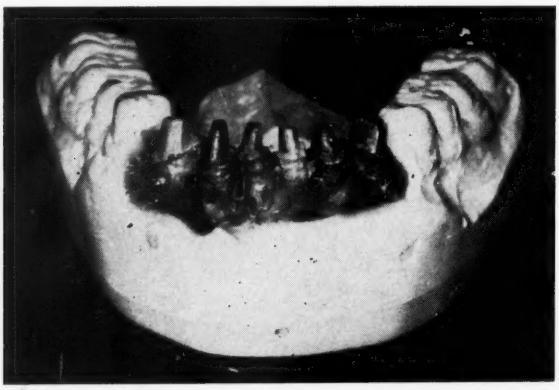

Fig. 4.—The lower incisors seen in Fig. 3 are prepared for full coverage and do not offer adequate frictional retention for the acrylic resin or low-fusing metal type of transitional crown. Transitional crowns cast in technique metal or gold are indicated.

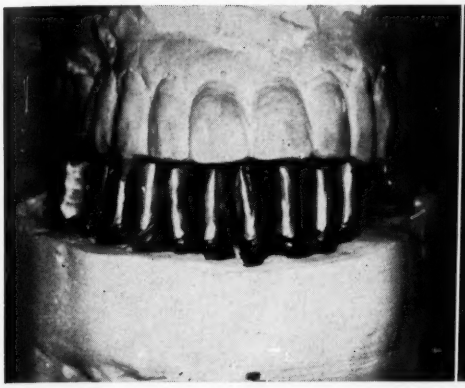

Fig. 5.

Fig. 6.

Fig. 5.—All mandibular transitional crowns have been adjusted in the mouth to the correct length to establish the vertical dimension and the centric relation.

Fig. 6.—The centric relation is recorded by means of cold-curing acrylic resin on the occlusal surfaces of the second molar and the first bicuspid transitional crowns. Corresponding crowns on the left side of the mandibular dental arch are similarly treated. These crowns may be returned to the mouth in any combination for comparison of occlusal relationships.

A copper band of a size that will furnish an adequate bulk of metal to form a crown somewhat larger in all dimensions than the finished crown is placed over the die and embedded in the Mouldine. The band should stand away from the die about 1.5 mm. at the gingival margin to allow space for adequate bulk. The low-fusing metal is poured into the copper band and forced down around the die by pressing a finger wrapped in a piece of rubber dam over the open end of the band. The metal is chilled and removed from the Mouldine, and the copper band is split with a disk and removed. Then the low-fusing metal is trimmed to the approximate shape of the crown, but with excess in all dimensions[3] (Fig. 2).

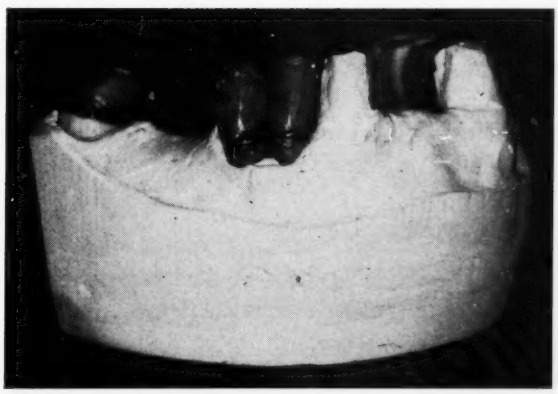

Fig. 7.—The occlusal plane is established in the mouth for a partially edentulous dental arch. It is permanently recorded by the transitional crowns.

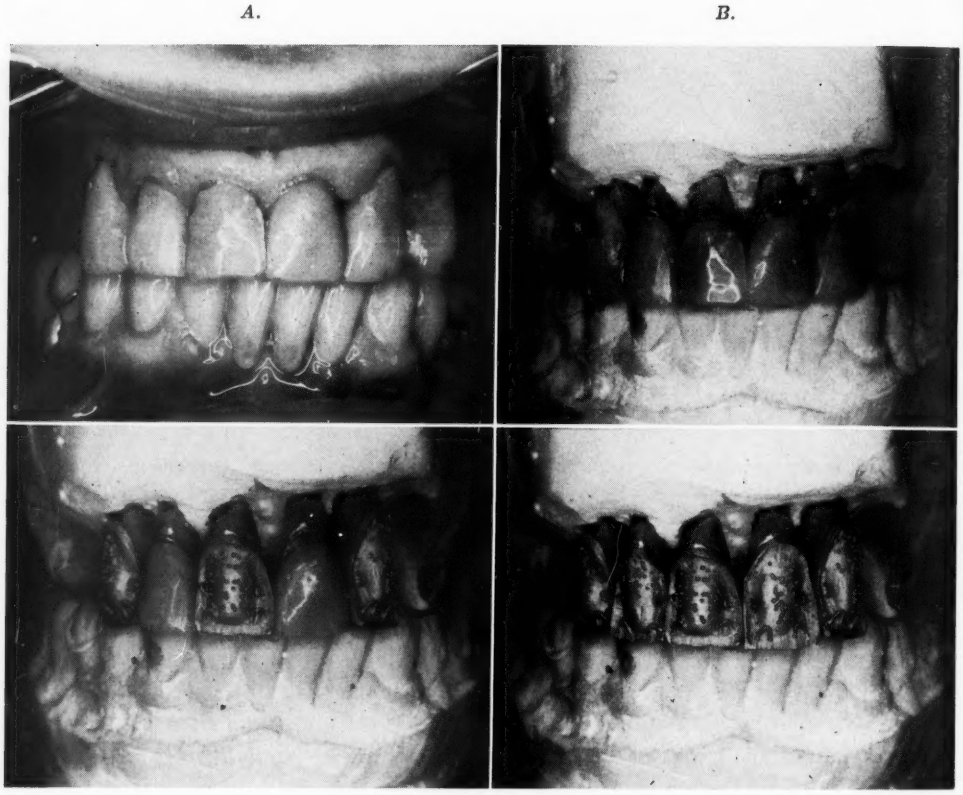

Fig. 8.—*A*, The alignment, length, color, and inclination of the maxillary transitional crowns have been established. The crowns will be transferred to the working casts for duplication in metal. *B*, The transitional crowns serve as guides for the waxing of the permanent crowns. *C*, Alternate transitional crowns are guides for the waxing of the alternate gold crowns. *D*, The castings are completed.

When the lower anterior teeth are extremely small and short, so that a snugly fitting transitional crown is difficult to prepare, gold alloys of silver and copper[4] or technique metal may be used for casting these crowns. A slight overextension beyond the finish line of the preparation will make the crown fit tightly. These crowns should be made with excess bulk in all dimensions and trimmed as necessary to fit the tooth in the mouth (Figs. 3 and 4).

USES OF TRANSITIONAL CROWNS

Determination of Centric Occlusion.—A device must be used in occlusal reconstruction which removes guesswork from the determination of centric occlusion. Transitional crowns serve this purpose.

One tooth, preferably a molar, on each side of the same dental arch is prepared for full coverage. Transitional crowns with excess length are prepared. The vertical measurement is made with the aid of nose and chin markings.

The transitional crowns are seated firmly on the two prepared molars. Then, they are trimmed so that the desired vertical dimension of occlusion is established. The use of the excessively long transitional crowns quickly reveals deflective occlusal contacts in the course of grinding them to the correct length. It is not necessary for either the dentist or the patient to exert force to penetrate a material used for the interocclusal registration. The temporomandibular joints are neither strained nor tilted.

As the preparation of the remaining teeth proceeds, their respective transitional crowns are adjusted in the mouth to the correct length. The two original transitional crowns are used as guides. After all of the crowns have been fitted and adjusted, the centric occlusion and the path of closure may be observed (Fig. 5).

Preservation of the Vertical Dimension Record.—In rehabilitation procedures, the vertical dimension of occlusion must be recorded in an unyielding substance so that it can be preserved. Time spent in the determination of the vertical dimension may be wasted if the result is recorded in wax. Seating the casts in wax records often results in inaccuracies because of the yielding nature of the wax. Also, the seating of an occlusion rim containing indentations of from ten to twenty-eight teeth on casts, or on the teeth themselves, does not permit a visual comparison of the relations of the assembled casts with the relations in the mouth.

Occlusion rims cannot be on the casts and in the mouth at the same time. Some of the transitional crowns can be in the mouth while others are on the casts. When the transitional crowns have been adjusted to the proper occlusal height and to centric occlusion, the working casts containing the assembled dies can be related to each other by three or four transitional crowns. The relationship of the crowns on the casts can be compared with the relationship of the other transitional crowns in the mouth. The relative positions of the upper and lower incisors in the mouth and on the casts can be observed and minute differences can be detected.

Preservation of the Centric Relation Record.—When all the teeth have been prepared for crowns, the occlusal stops offered by the teeth no longer exist. The dentist is confronted with the problems of re-establishing centric relation and of relating the maxillary and mandibular casts to each other for mounting on the articulator. Stops of some kind must be used. Many types of stops have been used, but all of them are inadequate. The interocclusal waxes and pastes are not rigid and permanent. The clutches, balancers, and needle point tracers are bulky. All records and methods of this type impinge on soft tissue, and they hide the teeth in the mouth and on the casts at times when the occlusal surfaces should be observed.

With transitional crowns in place on the teeth and properly adjusted for occlusion and vertical dimension, the jaws may be related to each other by cold-curing acrylic resin. The resin is built up on a minimum of three transitional crowns. For example, the resin is added to the crowns on the lower right and left first molars and a central incisor. Then the patient is instructed to close in centric relation. Any errors are immediately apparent because all of the other transitional crowns may be observed unhindered by the recording medium. The mandible

is held in centric position while the resin sets. During this time, the dentist may mold the still soft resin against the buccal surfaces of the opposing teeth so that a positive, solid record results. When the resin has set completely, the transitional crowns are transferred to the casts to see if centric relation is the same on the articulator as in the mouth.

By alternating selected transitional crowns from the casts to the mouth and from mouth to casts, the relationships can be rechecked repeatedly (Fig. 6).

The use of transitional crowns is of great value when a hinge axis registration has been made. The process of the hinge axis determination and recording is often futile if its preservation and transfer to the articulator depend upon the uncertain wax records commonly employed.

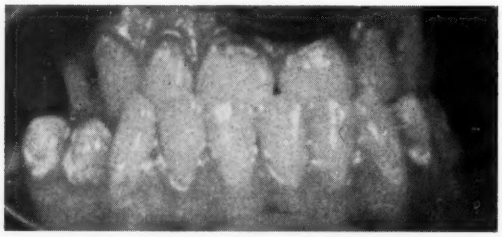

Fig. 9.—Class III occlusion is accentuated by the loss of the posterior teeth. The patient insisted that a normal overlap of the incisors be developed in the restorations.

Establishing the Occlusal Plane.—When one arch is edentulous and the opposing arch is partially edentulous, the location of the occlusal plane presents special problems. The determination of the portion of the available interarch space to be occupied by the complete denture and the portion to be occupied by the fixed or removable partial denture cannot be determined on the articulator. Transitional crowns on the prepared teeth can be adjusted in the mouth so their length will be correct for the vertical relation of the jaws and for the level of the tongue. The length of the lower incisors is determined in relation to the lip line. With an occlusion rim on the edentulous arch, compromises may be developed so that esthetic considerations may be settled before the casts are mounted on the articulator (Fig. 7).

Solution of Problems of Esthetics.—Transitional crowns provide a means for determining the inclination, alignment, and length of the incisors. Frequently, the incisors have an abnormal length in periodontally treated dentitions where gingivectomy has been performed. The time to decide whether the maxillary or mandibular incisors are better able to absorb this apparent increase in length is before the metal crowns are made. Often, the illusion of a shorter tooth can be gained by overlapping proximal surfaces, by varying the length of incisors in the same dental arch, by varying the incisal inclinations, or by lengthening the mandibular incisors at the expense of the maxillary incisors. Incisal guidance may be planned so that articulator adjustments may be correlated more closely with mouth conditions (Fig. 8).

The incisal inclination and incisal guidance are of special importance in Angle class II, division 2 occlusions, particularly when orthodontic treatment has been ruled out. Class III occlusions also present a special problem in esthetics. The effort to correct this condition by reversing the relative positions of upper and lower incisors may result in excessively long maxillary incisors, and a compromise may be necessary. Transitional crowns are useful for this purpose (Figs. 9 and 10).

Protection of the Finished Crown.—Gold copings that are to be a part of the finished restoration must be handled with care, but some abuse is unavoidable. Once the gingival margins of copings have been tested with a fine explorer and have been proved accurate, they should be handled as little as possible. Nevertheless, a coping must be fitted at its first trial in the mouth, and it must serve as a receptacle for low-fusing metal or as a die seat in the working cast. It must be waxed upon, cast against, and soldered to in the assembly process. This is a lot to ask of a thin gold casting.

Copings are used to seat the die in the plaster impression. Transitional crowns do this equally well. Also, copings are used in the multiple soldering operation, which is not dependable. The advantages of the transitional crown technique are not possible with the coping technique.

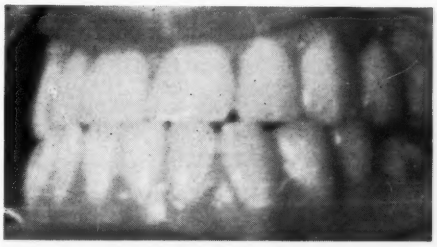

Fig. 10.—Same patient as in Fig. 9. The maxillary incisors have been prepared for full coverage and the transitional crowns are in place so the normal overlap of the anterior teeth can be observed. The incisors were excessively wide and had an unattractive labial inclination. As a compromise, an edge to edge relation of upper and lower incisors was agreed upon.

Resetting the Articulator.—Complicated articulators with many adjustments are used in reconstruction techniques. The many adjustments may be disturbed in the course of the procedures. Also, it is sometimes necessary to work with casts for more than one patient on a single articulator. To reset the articulator may be difficult, if not impossible.

Replacement of transitional crowns on their dies makes the rechecking and resetting of the adjustments of the articulator possible.

Locating Deflective Occlusal Contacts.—When only one to three teeth are to be replaced by a fixed partial denture, the detection of deflective occlusal contacts is still a vital consideration.

Transitional crowns placed on the prepared abutment teeth for a unilateral fixed partial denture offer a means of revealing deflective contacts anywhere

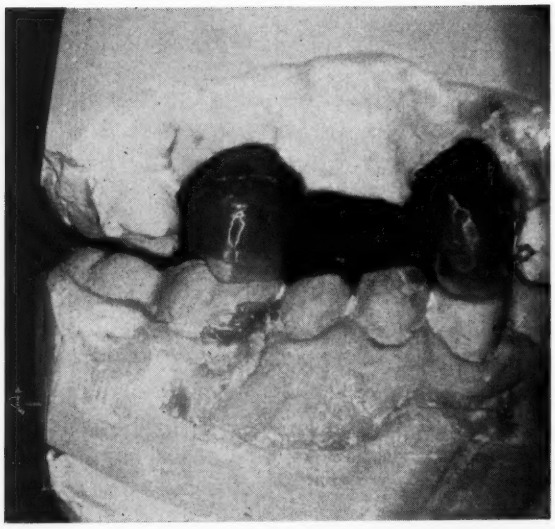

Fig. 11.—The transitional crowns disclosed an unbalanced occlusion. The second molar lacks contact with the opposing teeth. The existing fixed partial denture on the opposite side had been in premature contact over its entire length.

in the mouth. As the length of the transitional crowns is adjusted, articulating paper will reveal deflective occlusal contacts as the length of these crowns is reduced (Fig. 11).

A typical situation of this type is encountered when a third molar is used as the distal abutment for a fixed partial denture. Repeated occlusal adjustment may result in perforation of the distal abutment crown. Deflective occlusal contacts on third molars are often difficult to detect. The use of transitional crowns will avoid perforations of the gold crown by revealing the contact before the fixed partial denture is constructed.

DISCUSSION

The reconstruction of dental occlusions with other than orthodontic techniques is a hazardous procedure. Reconstructing a dental occlusion by operative methods offers the dentist a measure of freedom that is awesome to contemplate. In the course of his work, countless decisions must be made, and upon them rest the welfare and comfort of the patient. The nature of the response of the dental tissues is only one of the factors involved. The patient's emotional response is of equal or greater importance and is much more difficult to control.

No situation is so fraught with anguish as when the dentist is confronted with a dentally rehabilitated, emotionally disturbed patient. The fact that the occlusal reconstruction is largely irremediable does not tranquilize the dissatisfied patient. It seems to increase the tension by the very nature of its permanence. This makes it imperative that reconstruction procedures be accomplished with materials and devices that permit alteration and adjustment during the course

of the work. These techniques must permit constant observation, rechecking, and reappraisal. In some instances, the patient must be allowed to participate in the decisions. The transitional crown technique fulfills these requirements.

SUMMARY

The technique of fabrication and the uses of transitional crowns have been described. The transitional crown is useful in making fixed dental prostheses and in extensive occlusal reconstruction. These crowns have valuable uses in (1) the determination of the vertical dimension of occlusion, (2) the determination of centric relation, (3) the preservation of the centric relation records, (4) the establishment of the occlusal plane, (5) the solution of problems of esthetics, (6) the protection of the finished crowns, (7) the rechecking of articulator settings, and (8) the location of deflective occlusal contacts.

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OPERATIVE DENTISTRY

RESTORATION OF TEETH WITH SILVER AMALGAM

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SILVER AMALGAM endured a stormy history to become the most widely used restorative material in dentistry. It was first introduced in this country in 1833. While the earliest amalgam was a very unstable filling material, the fact that its earliest users were for the most part charlatans was even more reason for organized dentistry to oppose its use. In 1843, the American Society of Dental Surgeons announced it to be malpractice to use amalgam, and in 1845, this organization required a signed pledge by all members stating they would not use it. A surprisingly large number of dentists were expelled for refusal to sign the pledge, but it was 5 years later before the rule was rescinded. Although this marked the end of the "Amalgam War" and reunited organized dentistry, opposition to the use of amalgam continued.

In 1874, Thomas Hitchcock of New York introduced the micrometer to dentistry and opened the way for more accurate studies of the properties of dental materials. G. V. Black in 1894 began his studies which resulted not only in greatly improved alloys but the systematizing of cavity design as well. While Black was concerned with the standardization of the manufacture of silver alloys and the design of cavity preparations, the investigators who followed were more interested in the manipulation of the material. In 1919 and the early twenties, Arthur W. Grey studied the effect of variations in manipulation on the physical properties of amalgam, as did Marcus L. Ward later in the same decade. William E. Harper was another research worker of this period.

Cooperative research was started by the American Dental Association and the National Bureau of Standards in 1928, and it was through this joint work that a cosmos of testing methods was developed. The interferometer made the measurement of dimensional changes more accurate, and the work of G. C. Paffenbarger, N. O. Taylor, W. T. Sweeney, Wilmer Souder, C. G. Peters, and others at the National Bureau of Standards is well known to the student and clinician. Of the

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more recent investigators, the names of James T. Sweeney, E. Carl Miller, Claude C. Cannon, George M. Hollenback, Miles R. Markley, Ralph W. Phillips, Warren Harvey, Drexel Boyd, and John H. Mosteller are familiar to those who read the dental literature regularly.

While the entire history of amalgam is an interesting one,[1,2] in this article the trend during the last 15 years in various phases of amalgam restorative work will be reviewed in order to best arrive at the present status of the material.

CAVITY PREPARATION

Two surveys of amalgam failures[3,4] demonstrated that a majority of these failures were due to faulty cavity preparation, with underextension the most commonly committed error. These surveys were conducted several years ago and most of the fillings evaluated were probably made several years prior to that. Undoubtedly, underextension of amalgam preparations was widespread at that time. Prior to World War II when most dentists were using chrome-steel rotary cutting tools operating at approximately 3,600 r.p.m., the proper extension of cavities was a laborious task. Economic conditions were poor and the demand for operative dentistry was low. Amalgam fillings commanded such a poor fee that they were not conducive to prolonged operative procedures. Only the most conscientious dentists correctly extended their cavities.

During the war, the cutting tools were made of inferior materials and most civilian dentists had more patients than they could adequately treat. The desire for dental service was high, but unfortunately many dentists were more interested in the more remunerating phases of dentistry. During both the prewar and the war period, errors in cavity preparation were most frequently on the underextension side.

THE HIGH SPEED ERA

In the postwar period, dentistry entered the first stage of "high speed," that is, the use of diamond cutting tools operating at from 12,000 to 20,000 r.p.m. Large diamond disks were very popular, for the increased cutting perimeters of these instruments increased the revolutions per minute to 60,000 or more and thus offered greater cutting efficiency. Armed with this new technique and the sincere desire to avoid the underextension which had been characteristic of the less dedicated dentists in the past, many well-meaning dentists, including myself, overextended cavity preparations in the name of good operative dental procedure. Much sound tooth structure was sacrificed in order to facilitate the cutting of the cavity with large diamond instruments. Fig. 1 shows amalgam restorations made 12 years ago and is an illustration of poor operative procedure. The teeth were unnecessarily weakened by the overextension of these cavity preparations. All large amalgam fillings cannot be indicted for overextension. The treatment of neglected caries or the replacement of old fillings frequently requires gross extension, but the restorations in Fig. 1 were placed in virgin cavities. The disk approach invariably invited overextension (Fig. 2).

Fortunately, operative dentistry is now in a later stage of high speed, which some essayists have termed "super speed" or "ultra speed." When operating above

100,000 r.p.m., whether the handpiece be air, water, or belt driven, sound tooth structure is easily removed with small cutting tools. While there is no excuse for failure to properly extend the cavity, neither is it necessary to overextend it through the use of large cutting tools.

With the newer handpieces, the cavity is easily opened and quickly extended to the proper limits, but refinements in the preparation must still be accomplished with hand instruments. The injudicious application of the super speed handpieces can result in tooth butchery, but properly used, the newer equipment allows good operative procedures to be performed more easily; not necessarily faster, but more easily.

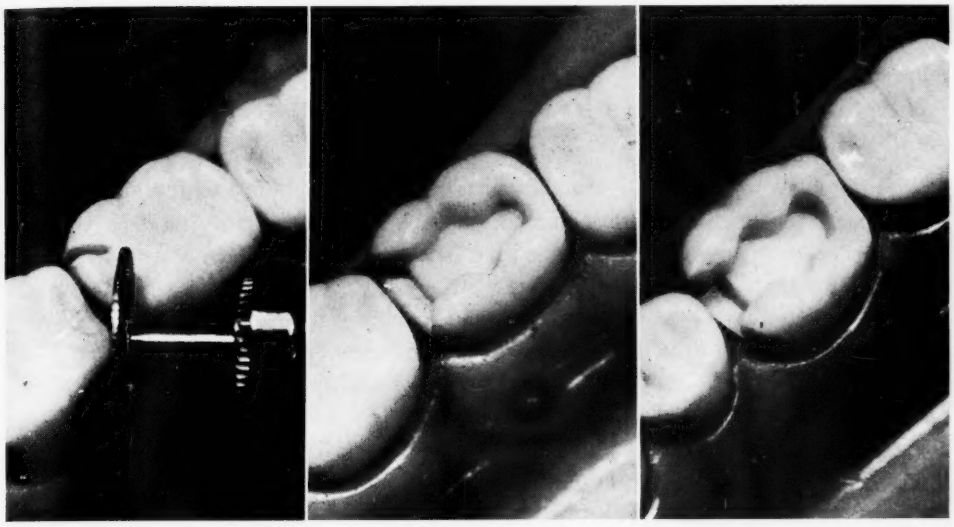
IDEAL CAVITY PREPARATION

Fig. 3 is of an ideal class II cavity preparation for amalgam.[5] The occlusal orifice must be extended to include all developmental grooves, the pulpal floor should be flat and seated at least 1 mm. beyond the dentoenamel junction, and the buccal and lingual cavity walls should converge slightly toward the occlusal surface

Fig. 1.—Overextended class II amalgam restorations.

to give the inverted truncated cone form, while the caries-free proximal cavity wall should be either perpendicular to the pulpal floor or diverge slightly toward the occlusal surface in order to preclude the chance of undermining the intact proximal marginal ridge. Bevels *must* be avoided on the margins of all preparations for amalgam.

The buccal and lingual walls of the proximal portion of a class II cavity should converge toward the occlusal surface and should be extended laterally into the interproximal embrasure no more than is necessary to avoid contact of the cavity margin with the approximating tooth. Greater extension assures no increase in caries immunity and needlessly weakens the tooth. Amalgam comes closer to hermetically sealing the cavity than does an inlay, and it has an anticariogenic property not possessed by the inlay, but the remaining natural tooth structure cannot be strengthened with an amalgam restoration as it can be with a casting. Any time a tooth is filled with amalgam it is weakened. The less tooth structure that must be removed,



A. *B.* *C.*

Fig. 2.—*A*, A diamond disk approach for class II cavity preparation. *B*, Overextension of the buccal and lingual walls of the proximal portion of a class II cavity preparation for amalgam which results from the disk approach. *C*, The correct extension of the buccal and lingual walls of the proximal portion of a class II cavity preparation for amalgam.

the less the tooth is weakened. Extension should be as conservative as possible and still be consistent with the extent of the decay and with proved preventive procedures.

The proximal portion of the class II amalgam filling should be as self-retentive as possible. It should not depend entirely on the occlusal isthmus to be held in the cavity. This can be accomplished by establishing the dovetail mortise form, i.e., greater occlusal convergence of the buccoaxial and linguoaxial line angles than the occlusal convergence of the buccal and lingual walls of the proximal portion of the cavity. This will give the gingival floor of the cavity a dovetail shape, thus locking

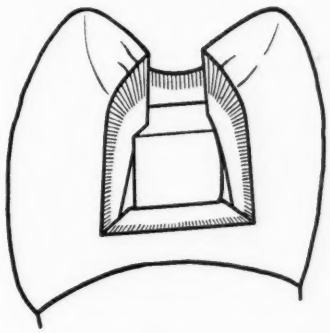


Fig. 3.—An ideal class II cavity preparation for amalgam. Note the inverted, truncated cone and dovetail mortise forms.

the amalgam into the proximal portion of the cavity. The proximal retention can be further increased by making a slight groove with an angle former along the gingivoaxial line angle.

AMALGAM ALLOYS

Although finely cut amalgam alloys have been available to the dental profession for a quarter of a century, they have become popular only during the last 10 years. Finely cut alloys provide the dentist with a better control of the dimensional changes of the material, have a greater crushing strength, and present a smoother surface on the completed restoration which takes and maintains a better polish.[6,7]

Any zinc-containing amalgam alloy that is contaminated with moisture will expand prodigiously,[8] lose up to one-third of its ultimate strength,[9] and tarnish badly. For these reasons, the material must not be handled, and best results are assured by the routine use of the rubber dam. I practiced for 10 years without using the rubber dam and attempted to accomplish good operative dental procedures; however, since adopting the routine use of the rubber dam in my practice, not only has the quality of my work improved but good operative dental service has become easier to provide. The rubber dam allows such improved vision that better cavity preparations invariably result, and it offers the best assurance of the dry field so necessary for good amalgam restorations.

Although nonzinc alloys were first introduced many years ago, there has been a renewed interest in them during the last few years and several new ones have been placed on the market. The contamination of a nonzinc alloy will not result in the delayed expansion or loss of strength characteristic of alloys containing this element, but Sweeney[10] reported pitted surfaces on fillings built of moisture-contaminated nonzinc amalgam and I[11] observed a more severe corrosion of moisture-

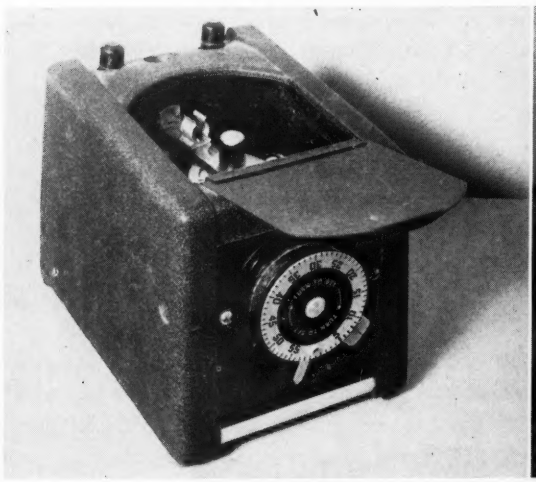


Fig. 4.

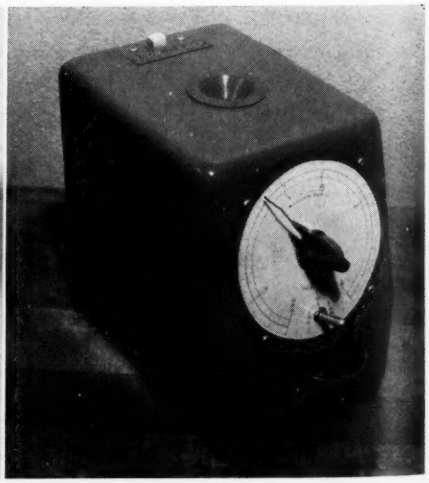


Fig. 5.

Fig. 4.—The Amalgamaster, designed by Roy E. Barr, D.D.S.
Fig. 5.—The Expressor, designed by E. O. Hall.

contaminated nonzinc amalgam fillings than of moisture-contaminated zinc-containing amalgam fillings in the same mouths. An absolute dry field is essential with either type alloy if a restoration free of corrosion is the goal of the dentist. Working in an excess of saliva is not conducive to good operative dentistry.

MATRIX ADAPTATION

Many different mechanical matrix retainers have been in use for decades, but most of them fail to reproduce the missing proximal surface of the tooth. Therefore, many good clinicians use individually tailored bands supported by a gingival wedge and modeling compound. Of the mechanical retainers, the one designed by Toffelmire[12] is by far the best, chiefly because of the arcuate shape of the band. This bow shape allows good adaptation to the parabolic shape of the tooth and yet establishes the proximal marginal ridge in contact with the adjacent tooth. Phillips[13] made a study of several matrix techniques used by well-known clinicians, and, as might be expected, they all gave good results in the hands of their advocates. All of these techniques had two things in common: (1) proper contouring of the band to form a convex proximal surface and (2) wedging of the gingival margin.

MERCURY TO ALLOY RATIO

Many years ago, Gray[14] pointed out the importance of a proper mercury-alloy ratio, and more recent investigation[15] has substantiated his observations. Various proportioning devices are available to the profession, and, while a recent study by Ryge[16] disclosed that some of the most popular of these are more inconsistent than others, inexpensive ones can be obtained which will, within practical limits, give a sufficiently accurate ratio. Although one new technique[17] makes use of an original ratio of less than 50:50, most dentists still prefer to start with the conventional higher mercury ratio recommended by the manufacturers and then remove the excess by means of a squeeze cloth.

After the mix has been completed, the excess mercury should be removed promptly from the entire mass. Plasticity may be maintained by mulling the material in a clean piece of rubber dam during condensation.[18] The leaving of mercury in the mass in order to retard setting results in an inability to remove as much mercury. Phillips[19] demonstrated a definite increase in the mercury content of specimens which were condensed after the material had been allowed to set on the bracket table for a few minutes.

There has been considerable research on the relationship between the residual mercury content of amalgam and its compression strength.[20-22] There appears to be little correlation as long as the mercury content remains between 45 and 54 per cent.[23] The slight increase in strength of amalgam having less than 45 per cent mercury is probably of only academic interest, for material this dry will not condense well clinically. There is a dramatic loss of strength when the mercury content exceeds 55 per cent.[23] Frequently in practice, amalgam restorations as much as 60 per cent mercury are built, but the distribution of the mercury is more important clinically than is the total mercury content of the entire restoration. Although the

total mercury content may be less than the critical 55 per cent, poor technique can result in mercury rich material at the marginal areas which are naturally more subject to fracture and deterioration.

Besides this loss of strength, excess mercury in amalgam results in increased expansion. This expansion is not of the same magnitude as that caused by moisture contamination of zinc-containing alloys, and it is probably of no clinical significance. A recent clinical investigation* has demonstrated the visual effects of excess mercury in terms of marginal disintegration and surface roughness.

A study[24] was made of the characteristics of two centrifuge machines for the removal of mercury from amalgam (Figs. 4 and 5). One of these is now available.† While the use of neither of these machines is necessary for prompt and correct removal of free mercury, they may serve as a convenience to dentists in the future. Both machines produced consistent residual mercury content in the amalgam (Fig. 6), and certainly there is less opportunity for error as compared to the unstandardized use of a squeeze cloth. One attribute of the machines is that they require the immediate removal of the free mercury from the entire mass as soon as the mixing has been completed.

Some manufacturers now provide preweighed pellets of alloy to which the desired ratio of mercury is added by a mechanical dispenser. Most mercury volume dispensers are very accurate, and this is a convenient manner in which to obtain a consistent ratio.

MIXING OF AMALGAM

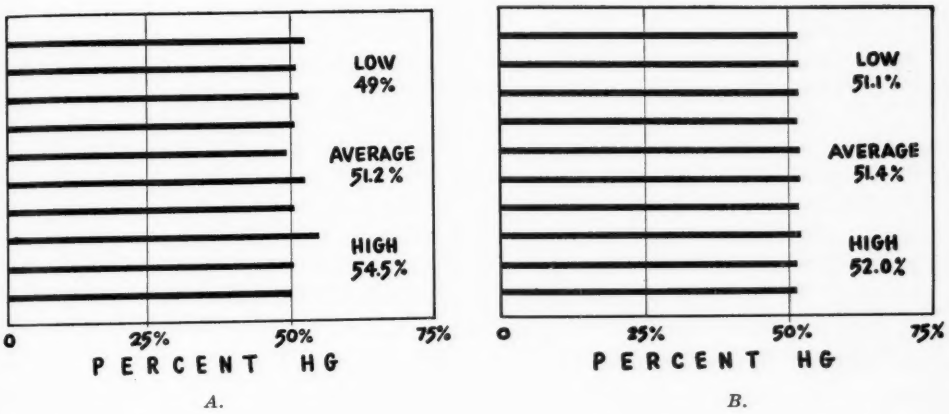
Consistent mixes of amalgam are easily obtained with a high speed mechanical amalgamator, and this machine is particularly convenient when multiple mixes are necessary for large restorations. Some have criticized it because of fear of overmixing. An overmix of amalgam is almost a clinical impossibility. The material would have to be mixed until it did not have sufficient plasticity to allow the dentist to condense the filling properly. The slight contraction of amalgam that can be demonstrated in the laboratory is of no clinical importance.[25] Thorough mixing yields an amalgam with a greater early crushing strength and the ability to take and maintain a better polish.[26] Thorough mixing precludes the deleterious results of undermixing.

While more thorough mixing is advocated, the placing of partially crystallized material back into the amalgamator and remixing in order to regain plasticity will result in a weak and poorly adapted filling. Amalgam loses strength rapidly after the mix has been completed, and any material that has not been condensed within 3 minutes after the start of the amalgamation should be discarded and a second mix made. Mercury cannot be added to partially crystallized amalgam and then remixed without resulting in a restoration plagued with all of the disastrous results of excess mercury.

The pellets require the use of a metal pestle for proper mixing. No more than three pellets should be amalgamated at one time in any of the capsules available

*R. Nadal and R. W. Phillips: Unpublished data.
†Amalgamaster, Torit Mfg. Co., St. Paul, Minn.

today, and they should be mixed for 18 to 20 seconds in a high speed amalgamator.* If a slower machine is employed, the pellets and mercury should be mixed a minimum of 30 seconds. Because of the necessity of breaking up these pellets through more thorough mixing, their setting time will be shorter and thus there is less time to condense the filling. The mixed material has a tendency to adhere to the inside of the capsule when the large metal pestles are used with the pellets. Thus, it is very difficult to clean the capsule before making the next mix. We use a ¼ inch steel ball bearing as a pestle. The mixed amalgam comes out in a clean ball after each mix and leaves no portion of the mass behind in the capsule.



A. *B.*

Fig. 6.—*A*, The Amalgamaster demonstrated a standard deviation of only ± 1.4 per cent, while *B*, the Expressor standard deviation was only ± 0.4 per cent. With each machine, 18 seconds of high speed amalgamation was used; with the Amalgamaster, 8 seconds of centrifugation, with the Expressor, ¼ second.

CONDENSATION

Condensation is a very important step in the amalgam technique for it regulates the adaptation of the material to the cavity walls, greatly influences the crushing strength of the restoration, and determines the distribution of the free mercury. As previously explained, the excess mercury should be removed from the entire mass as soon as the mixing has been completed. This will give a homogeneous, heavy-bodied material which will resist the pressure of the condenser points. A very slight amount of mercury should appear at the surface of the material under heavy packing pressure. Small condensing instruments and a heavy packing pressure should be used to assure the adaptation of the material into all of the irregularities of the cavity. The principles of good condensation of amalgam require the use of many and small increments of material placed in the cavity under heavy pressure, followed by a gross overpack on the occlusal surface and margins.

A well-designed amalgam carrier is essential for the addition of many and small increments. Physical effort is necessary in order to exert heavy packing pressure when condensing the restoration by a hand technique. Large condensers are

*Wig-L-Bug, Crescent Dental Mfg. Co., Chicago, Ill.

used with a rocking movement on the occlusal surface to build an excess of a full millimeter. The excess is then immediately carved away with a sharp instrument.

There are a number of "automatic" condensers on the market. These may be air activated (Hollenback, Cleve-dent), mechanically activated (Midwest), electromallets (McShirley), ultrasonic vibrators (Cavitron), sonic vibrators (Kerr), or low frequency vibrators (Wright, Chayes). With any instrument that delivers a blow there is the constant danger of inadvertently fracturing enamel margins, and the vibrators seem to pool free mercury at the margins of the cavity. The very slight increase in crushing strength that may be obtained with some of these instruments in the laboratory is of no clinical significance.[27] The choice between hand and mechanical condensation appears to be one of personal preference only.

CARVING, FINISHING, AND POLISHING

The completion of the restoration is more of an artistic endeavor than a reflection of scientific information. With the fast-setting, finely cut alloys, the matrix band can be removed almost immediately after condensation. Heavy burnishing should be avoided, for this tends to pool mercury at the margins of the filling. Great care must be exercised not to overheat the material during the finishing and polishing procedures, for this will bring mercury to the surface and result in pits and voids after the mercury diffuses back into the restoration. When the amalgam is heated to this point, the pulpal tissues are undoubtedly endangered as well. Properly manipulated amalgam will remain free from corrosion in most hygienic mouths.

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INFLUENCE OF CAVITY LINERS UNDER AMALGAM RESTORATIONS ON PENETRATION BY RADIOACTIVE ISOTOPES

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MARGINAL LEAKAGE TO RADIOISOTOPES, with penetration into the dentine and pulp, has been shown to occur around all filling materials in current clinical use. Silver amalgam fillings are included with those which have poor sealing qualities.[1-3]

The use of a cement base under deep amalgam restorations has been a common clinical practice to prevent thermal shock and death of the pulp. Massler and Barber[4] and Phillips, Schnell, and Phillips[5,6] showed that bases under amalgam restorations should also insulate against the galvanic action inherent in all amalgam restorations. Massler[7] showed that the base under an amalgam restoration should inhibit penetration of mercury into the underlying dentine and thus prevent discoloration of the tooth. This study introduces a fourth consideration: the influence that a base or liner may have on the marginal leakage around the amalgam restoration and the subsequent penetration into the dentine and pulp.

Since silver amalgam is the most common restorative material used and since bases under amalgam have been a point of particular interest during the past decade, it was considered important to test the effectiveness of a number of liners or bases in preventing ionic diffusion around such restorations. This testing was done with radioactive tracer solutions.

REVIEW

Originally, dye tracers were used to test the marginal integrity of various filling materials. These studies showed that acrylic resins, silicate cements, zinc phosphate cements, zinc oxide–eugenol, and temporary stopping (gutta-percha) did not adequately seal the margins against the ingress of large dye molecules, while gold foil, gold inlay, copper, and silver amalgam restorations did.[8-10] However, when small particles of ionic dimensions were used in the form of radioactive tracers, it was demonstrated that silver amalgam showed gross marginal leakage. This leakage was less than around acrylic resin or silicate cement but much greater than occurred around gold foil, gold inlay, and even copper amalgam restorations.[1,2,10,11]

Martin[12] and Amler and Bevelander[13] found that many of the cavity liners and medicaments used in clinical practice to reduce dentine permeability actually increased the permeability of the dentine to both dyes and the isotope P^{32}.

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As far as could be determined, there has been no previous comparison of the influence of various liners and bases placed under amalgam restorations on the marginal penetration of the isotopes as well as their penetration through the underlying dentine.*

METHODS AND MATERIALS

Class V cavities were prepared in 234 newly extracted human teeth. All teeth were from male patients 23 to 68 years of age. The cavities were lined or based according to the manufacturer's specifications with one of eight materials commonly used for this purpose.

Composition of Liners and Bases Used in This Study.—

Copalite varnish: "Contains certain natural rosins and solvents for these rosins."

Mizzy Poly-Liner: A film type of cavity varnish containing polystyrene, 70 per cent ethyl cellulose, 27 per cent staybellite ester, and 3 per cent betanaphthol, in a mixture of chloroform and xylene.

Chembar: Suspension of 6 per cent calcium hydroxide and 6 per cent zinc oxide in a chloroform solution of polystyrene.

Pulpdent paste: Suspension of 48.6 per cent calcium hydroxide in an aqueous methylcellulose solution.

Pulpdent liquid: Suspension of 8.7 per cent calcium hydroxide in an aqueous methylcellulose solution.

Zinc oxide–eugenol (fast-setting): Chemically pure zinc oxide powder mixed with eugenol liquid to a thick paste. One drop of a saturated solution of zinc acetate added to the mix, as an accelerator. Average setting time, 7 minutes.

Zinc oxide–eugenol with polystyrene (Weiss' formula): Clinically pure zinc oxide powder with 3 per cent zinc acetate crystals and 5 per cent bismuth subcarbonate added and mixed to a fine powder. Ten per cent polystyrene dissolved in eugenol liquid. A thick paste is mixed with an average setting time of 5 minutes.

Zinc phosphate cement (Fleck's cement): Refined zinc oxide powder and orthophosphoric acid liquid mixed as a thick paste. Average setting time, 3 minutes.

Procedure.—After an appropriate drying period, silver amalgam was condensed over bases or liners in the usual fashion. Each restoration was carved and permitted to harden for 15 minutes before immersion into the isotope solution.

The newly restored teeth were immersed in one of four different radioisotope solutions for a period of 24 hours: I^{131}, $S^{35}O_4$, Ca^{45}, or Na^{22} (Table I). These provided monovalent and divalent negatively and positively charged ions as tracers. To prepare these tracers, a measured quantity of concentrated radioactive isotope solution was diluted in distilled water to the activity required. The crowns of these teeth were immersed in 2 ml. of this solution placed in separate tubes. After the immersion period, the teeth were wiped with wet gauze, to remove any loosely adhering solution, and embedded horizontally in a quick-setting impression plaster with the class V restorations facing up and exposed. The teeth were sectioned by making two longitudinal cuts through the center of the filling, producing a plano-

*Since this article has been in press, a similar study has been reported by Phillips and Coauthors: J.A.D.A. 62:9-20, 1961.

TABLE I. CHARACTERISTICS OF ISOTOPES USED IN THIS STUDY

IONIC TRACER	COMPOUND	CHARGE	BETA-MEV	HALF-LIFE	CONCENTRATIONS USED* (μC PER ML.)	RADIOAUTOGRAPHIC EXPOSURE TIME (HR.)
I^{131}	NaI^{131}	−	0.605	8 days	25	6
$S^{35}O_4$	$Na_2S^{35}O_4$	−−	0.167	87 days	10	24
Ca^{45}	$Ca^{45}Cl_2$	++	0.254	163 days	10	6
Na^{22}	$Na^{22}Cl$	+	0.58	2.6 yr.	10	8

*pH 6 to 5.2.

parallel central slab slightly less than 1 mm. thick. During the sectioning, the teeth were washed with large quantities of cool running water. The tooth slab was polished on fine silicon carbon abrasive paper and dried. Radioautographs were then produced according to the procedures described by Going, Massler, and Dute.[10] Minimax extra fast dental x-ray film was used for all autoradiographs. An x-ray image was often superimposed on the autoradiographs to give a sharper outline and a more exact location of the isotope.[14]

Evaluation of Penetration.—The depth of penetration of each isotope around the amalgam filling and through each liner was assessed according to the system shown in Fig. 1.

Controls.—Two types of controls were used. In one series, the liners were placed under silver amalgam fillings as described above, and their effects were compared to amalgam fillings without liners. In the second series, each liner was applied to a cavity preparation and immersed into the isotope solution without placing an amalgam filling over it. The effectiveness of each liner in preventing penetration of the isotope into the dentine was then compared with open cavity preparations containing no liner and no filling. In this manner, the influence of each liner in preventing isotope penetration into the dentine was checked under two different conditions.

Number of Specimens.—Three specimens were used to test each liner in each series and in each one of the four isotope solutions. A replicate series of three additional specimens was run whenever the first series of autoradiographs was not consistent.

FINDINGS

Influence of Different Radioisotopes.—

Autoradiographs: Of the four isotopes used in this experiment, S^{35} produced the sharpest and most detailed autoradiographs, because of its low million electron volt value and short tracks (Figs. 2 and 4). Ca^{45} produced the next sharpest autoradiographs, followed by I^{131} (Figs. 3, 5, and 6). Na^{22} produced very diffuse pictures which were more difficult to interpret (Fig. 7).

Penetration: Radiosodium (Na^{22}) showed the deepest penetration. Intact enamel, as well as carious lesions, erosions, and abrasions, was deeply penetrated by Na^{22}. Therefore, the autoradiographic picture was often difficult to assess. Na^{22}

made most liners look bad. In contrast, Ca^{45} made most liners look good, because radiocalcium was found to be a poor penetrator. This is probably related to the empty phosphate bonds in the calcified tissues which attracted and held the free calcium ions. Both S^{35} and I^{131} penetrated well into defects in the tooth structure as well as filling margins.

Penetration appeared to be a function of chemical reactivity rather than of particle size or ionic charge, since positively charged sodium (Na^{22}) with an atomic weight of 22 was the deepest penetrator, whereas calcium (Ca^{45}) with an atomic weight of 45, and also positively charged, was the poorest penetrator. The two negatively charged isotopes, S^{35} as sulfate and I^{131}, with atomic weights of 99 and 131, respectively, showed the penetrating qualities most suitable for this study.

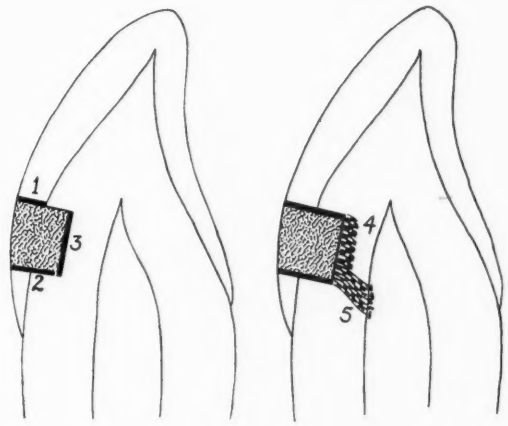

Fig. 1.—A diagram showing the method of assessing marginal and dentine penetration of isotopes: *(0)* no marginal penetration; *(1+)* superficial marginal penetration of isotope; *(2+)* marginal penetration of isotope to, but not including, the floor of the cavity; *(3+)* penetration of isotope all around filling margins and liner, including the floor of the cavity; no penetration into dentine; *(4+)* penetration of isotope through margins of filling and liner, into the dentine; *(5+)* penetration of isotope through margins of filling and liner, through the dentine, and into the pulp chamber.

Penetration of Isotopes in Controls.—

Unfilled cavities: All ionic tracers penetrated through the freshly cut dentine and into the pulp chamber (5+) within the 24 hour immersion period (Figs. 2, *A*, and 3, *A*).

Unlined amalgam restorations: The four radioisotopes also readily penetrated the margins of the unlined amalgam restorations and diffused into the underlying dentine and into the pulp chamber (5+) within the 24 hour immersion period (Figs. 4, *A*, through 7, *A*). These findings show that an amalgam filling alone, i.e., without a liner or base, does not adequately seal the cavity against the penetration of ionic tracers. Figs. 4, *A*, through 7, *A*, emphasize the need for impermeable liners or bases under *all* amalgam fillings if penetration to the pulp is to be prevented. This assumes, of course, that no sclerotic or secondary dentine formation occurs to prevent penetration in vivo.

Effects of Liners on Isotope Penetration.—

Film-forming liners:

Unfilled Cavities With Liner.—To test the effectiveness of the liner in preventing isotope penetration per se, cavity preparations were lined with Copalite varnish and Mizzy Poly-Liner and immersed in radioactive solutions of $S^{35}O_4$, I^{131}, Ca^{45}, and Na^{22} for 24 hours (without amalgam fillings). A decrease in the *quantity* of isotope penetrating the dentinal tubules was clearly evident in the autoradiographic picture, although some penetration by isotope to the pulp could be observed (compare Fig. 3, *B* and *C*, with 3, *A*).

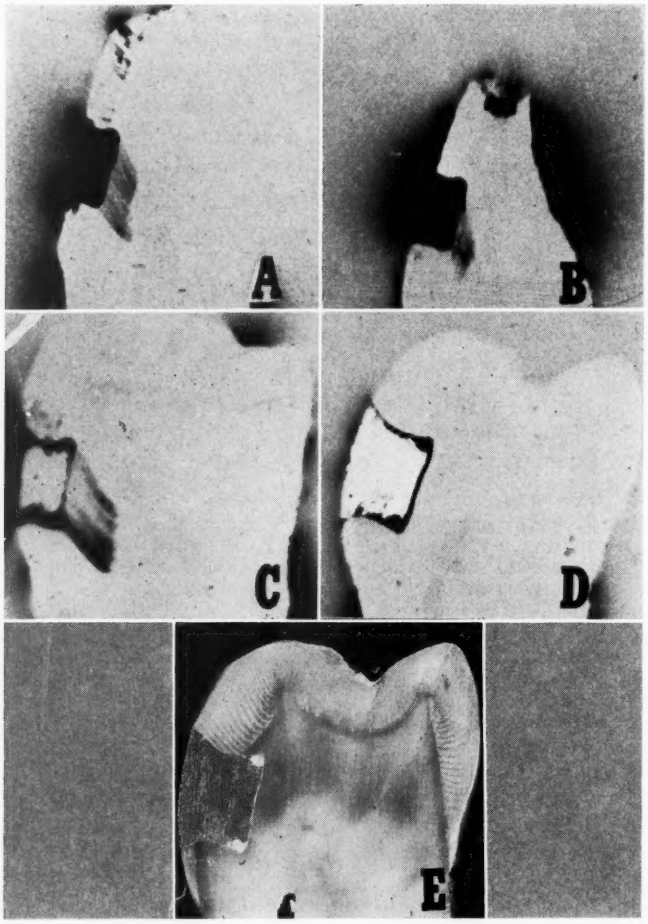

Fig. 2.—Autoradiographs of teeth showing the method of testing liners (Pulpdent liquid) by immersion in $S^{35}O_4$. *A*, Control specimen. Open cavity preparation without a liner or amalgam filling. Note the penetration of the isotope into the pulp chamber (5+). *B*, Open preparation lined with Pulpdent liquid. Penetration by isotope is slightly reduced in quantity but not in depth (5+). *C*, Silver amalgam filling without a liner (control). Note the penetration of the isotope into the pulp chamber (5+). Compare with *A*. *D*, Silver amalgam filling lined with Pulpdent liquid. Penetration is limited to the floor of cavity. There is no penetration into the dentine (3+). *E*, Histologic section of specimen shown in *D*.

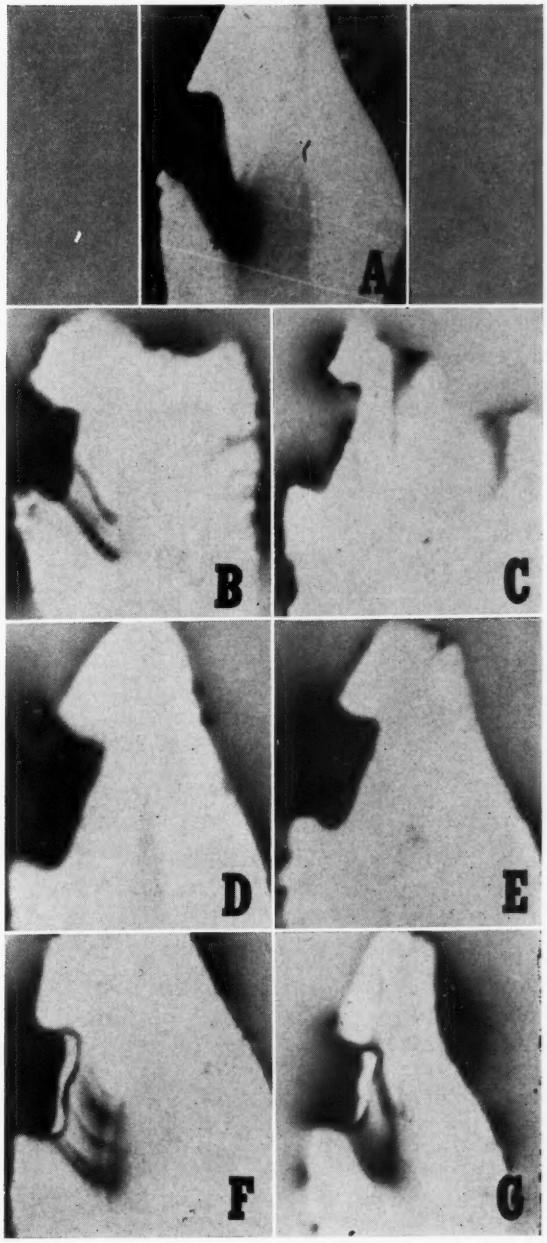

Fig. 3.—Autoradiographs of unfilled cavities immersed in Ca^{45}. *A*, An open preparation with no liner (control). There is isotope penetration into the pulp chamber (5+). *B*, Open cavity lined with Copalite varnish. Penetration is reduced in quantity but not in depth. *C*, Open cavity lined with Mizzy Poly-Liner. Penetration is markedly reduced, with a faint trace into the dentine. *D*, Open cavity lined with Chembar. There is no penetration into dentine. *E*, Open cavity lined with Pulpdent paste. There is no penetration into dentine. *F*, Open cavity lined with zinc oxide–eugenol cement. Penetration of isotope is slightly reduced in quantity but not in depth. Compare with unlined cavity in *A*. *G*, Open cavity lined with zinc phosphate cement. Penetration into dentine is slightly increased.

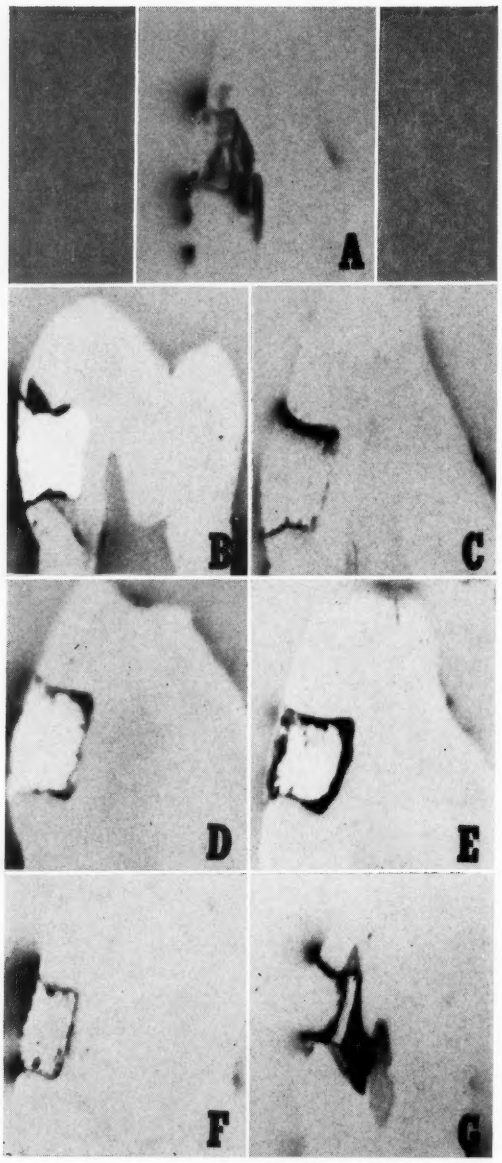

Fig. 4.—Autoradiographs of silver amalgam restorations immersed in $S^{35}O_4$. *A*, Silver amalgam unlined. Note penetration of isotope into the pulp chamber (5+) and into the amalgam itself. *B*, Silver amalgam restoration over Copalite varnish. Note the absence of penetration into the dentine. *C*, Silver amalgam restoration lined with Mizzy Poly-Liner. There is no penetration into the dentine. *D*, Silver amalgam restoration lined with Chembar. There is no penetration into the dentine. *E*, Silver amalgam restoration lined with Pulpdent paste. Note the concentration of the isotope within the liner. *F*, Silver amalgam restoration over a zinc oxide–eugenol base. There is a very faint penetration of isotope into the dentine. *G*, A silver amalgam restoration placed over a zinc phosphate cement base. Note the marked increase in isotope penetration into the filling and into the dentine. Compare with *A*.

Amalgam Restorations With Liners.—Copalite varnish under the amalgam restoration markedly decreased the depth of marginal penetration of the four isotopes used (from 5+ to 1+) and completely prevented penetration into the underlying dentine (Figs. 4, *B*, 5, *B*, and 6, *B*). Even the deeply penetrating Na^{22} was effectively confined to a superficial level, which no other liner or base did (Fig. 7, *B*).

Mizzy Poly-Liner under the amalgam restoration permitted marginal penetration of all radioactive ions around the filling walls, including the floor of the cavity. However, penetration of the isotope into the dentine was completely blocked except with Na^{22}, which penetrated superficially into the underlying dentine (Figs. 4, *C*, through 7, *C*).

Inasmuch as these two liners are thin films and susceptible to cracking during the drying process, isolated strips of deep penetration could sometimes be seen in the autoradiographic picture (see Figs. 4, *B*, and 6, *C*).

Conclusion.—Copalite varnish and Mizzy Poly-Liner reduced penetration of the isotope through the dentine to almost zero. Copalite varnish also decreased marginal penetration considerably. Poly-Liner permitted considerable marginal penetration.

Calcium hydroxide liners:

Unfilled Cavities With Liner.—Chembar and Pulpdent paste completely inhibited penetration of $S^{35}O_4$, I^{131}, and Ca^{45} into the dentine beneath the liners (Figs. 3, *D* and *E*). However, these liners showed marked concentration of the isotopes as seen by the heavy halation within the cavity. Na^{22} did penetrate through these liners, into the dentine and pulp chamber. The thin film formed by Pulpdent liquid was penetrated by all of the isotopes to the pulp chamber (Fig. 2, *B*).

Amalgam Restorations With Liners.—Pulpdent paste under amalgam permitted marginal penetration of all radioactive ions up to and including the floor of the cavity, but penetration into the dentine by all isotopes was completely elinated (Figs. 4, *E*, through 7, *E*). Radiosodium penetrated through the Chembar liner into the underlying dentine but not into the pulp. It also penetrated through the Pulpdent liquid into the pulp chamber. Concentration of the isotopes in the substance of the Chembar liner was also apparent (Figs. 4, *D*, through 7, *D*). Fig. 2, *D*, illustrates the concentration of radiosulfate in the substance of thinner Pulpdent liquid liner; Fig. 2, *E*, shows this thin film in a histologic ground section.

Conclusion.—Liners containing calcium hydroxide retard and even block dentine penetration but have little inhibitory effect on marginal penetration per se. In fact, marginal penetration may be increased slightly.

Cement bases:

Zinc Oxide–Eugenol Cement (Fast-Setting, With Zinc Acetate Accelerator).—

Unfilled cavities with liner: All the radioactive isotopes used, except S^{35}, penetrated through the zinc oxide–eugenol base, through the dentine, and into the pulp chamber although in reduced amounts (Fig. 3, *F*). $S^{35}O_4$ showed a decreased amount of penetration although it also reached the pulp chamber.

Amalgam restorations with liners: The zinc oxide–eugenol cement base under an amalgam filling did not reduce marginal penetration but did reduce dentinal

penetration somewhat. However, the radioisotopes were able to penetrate through the liner into the pulp chamber although in reduced amounts. Teeth immersed in $S^{35}O_4$ showed a marked decrease in the quantity of isotope penetrating to the pulp chamber (Figs. 4, *F*, through 7, *F*). The addition of polystyrene to the zinc oxide–eugenol mixture did not significantly influence the degree or path of isotope penetration.

Zinc Phosphate Cement.—

Unfilled cavities with liner: There was a marked penetration of each isotope through the zinc phosphate cement base into the pulp chamber (Fig. 3, *G*).

Amalgam restorations with liners: Zinc phosphate cement bases placed under silver amalgam restorations appeared to *increase* the marginal penetration by all of the isotopes used, and they markedly increased dentine penetration by $S^{35}O_4$ and Ca^{45} (Figs. 4, *G*, through 7, *G*). The autoradiographs in Figs. 4, *G*, and 6, *G*, show an increased density of the isotope within the dentine. The increased dentine permeability may be caused by the acid of the cement.

The amalgam in contact with the cement showed a ragged surface with increased penetration by the isotopes (Fig. 4, *G*). This suggests that the acid from the cement etched the amalgam in contact with it. The substance of the zinc phosphate cement did not absorb the isotopes as did the calcium hydroxide liners, but it did increase penetration of the isotope into the amalgam itself.

Conclusion.—From the point of view of ionic diffusion through the filling margins and subsequent penetration into the dentine and pulp, there appears to be some question as to the value of zinc phosphate cement as a base under amalgam restorations.

Summary of Findings.—

1. Copalite varnish and Mizzy Poly-Liner *decreased* the penetration of radioisotopes through the margins of amalgam restorations and completely blocked the penetration of isotopes into the dentine. These two liners were more effective than the other liners and bases tested.

2. The calcium hydroxide liners (Chembar, Pulpdent paste, and Pulpdent liquid) decreased markedly the penetration of the radioactive tracers into the underlying dentine but concentrated the isotopes within the liners to a marked degree. Marginal penetration was not affected and may have been slightly increased.

3. The zinc oxide–eugenol cement base decreased the penetration of the isotope tracers into the underlying dentine slightly but had little or no effect on the penetration of the isotopes through the filling margins.

4. Zinc phosphate cement *increased* penetration of the isotopes into the underlying dentine as well as into the amalgam itself in contact with the cement. Marginal penetration of the isotopes was also slightly increased.

DISCUSSION

Penetration of ionic tracers through the margins of all restorations, to a greater or lesser degree, is not a new finding. This study emphasizes the gross marginal

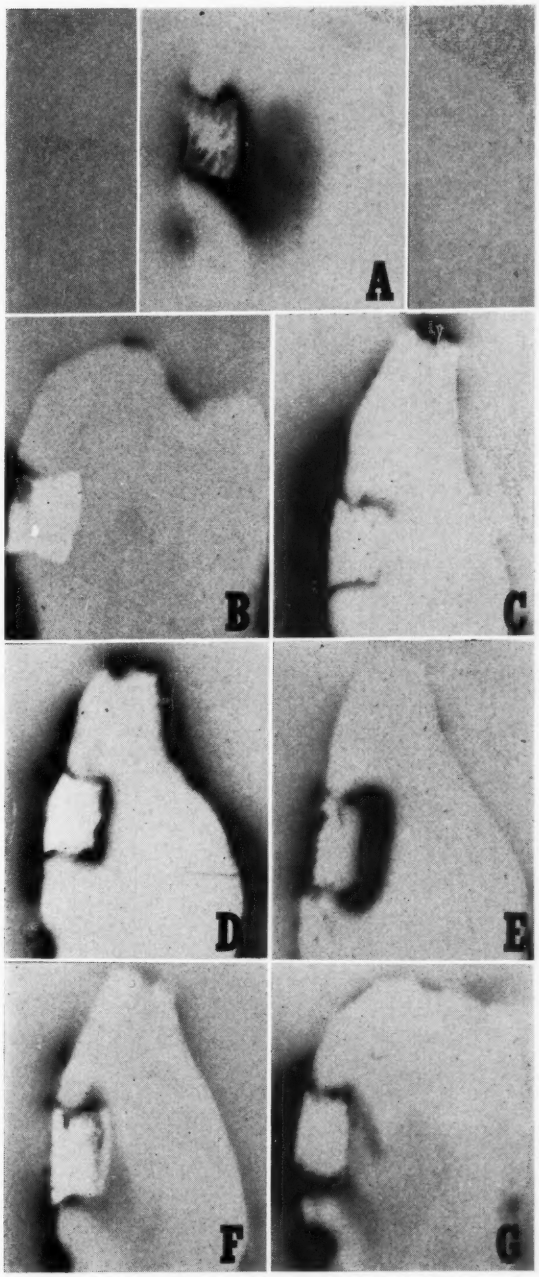

Fig. 5. Autoradiographs of silver amalgam restorations immersed in I^{131}. The specimens are arranged in the same order as in Fig. 4. Note the deep penetration of the isotope under the unlined restoration in *A*, the slight reduction under a zinc phosphate cement base in *G*, the greater reduction of isotope under the zinc oxide–eugenol cement base in *F*, and the marked reduction under the film-forming liners in *B* and *C*. Note also the concentration of the isotope by the calcium hydroxide liners in *D* and *E*.

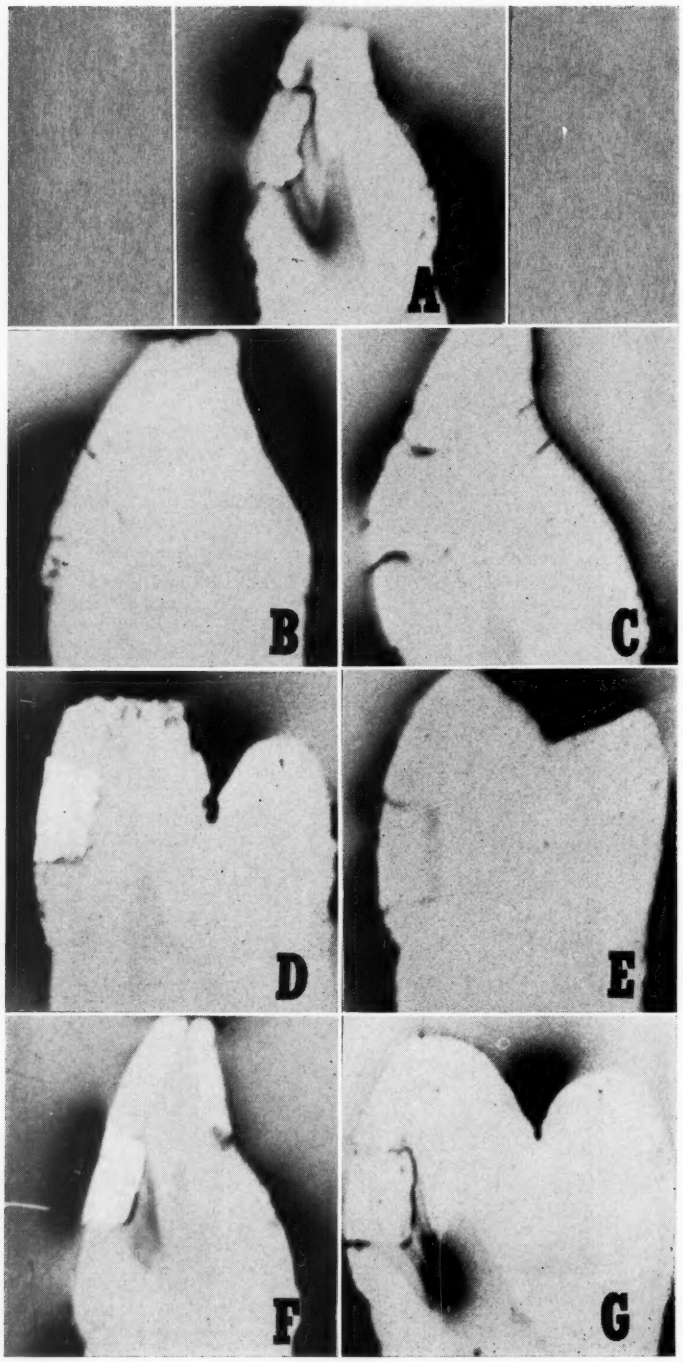

Fig. 6.—Autoradiographs of silver amalgam restorations immersed in Ca^{45} showing data similar to those described below Figs. 4 and 5. Note the increased penetration of Ca^{45} under the zinc phosphate cement base in *G*. Note the reduced penetration of Ca^{45} as compared with S^{35}, I^{131}, and Na^{22}.

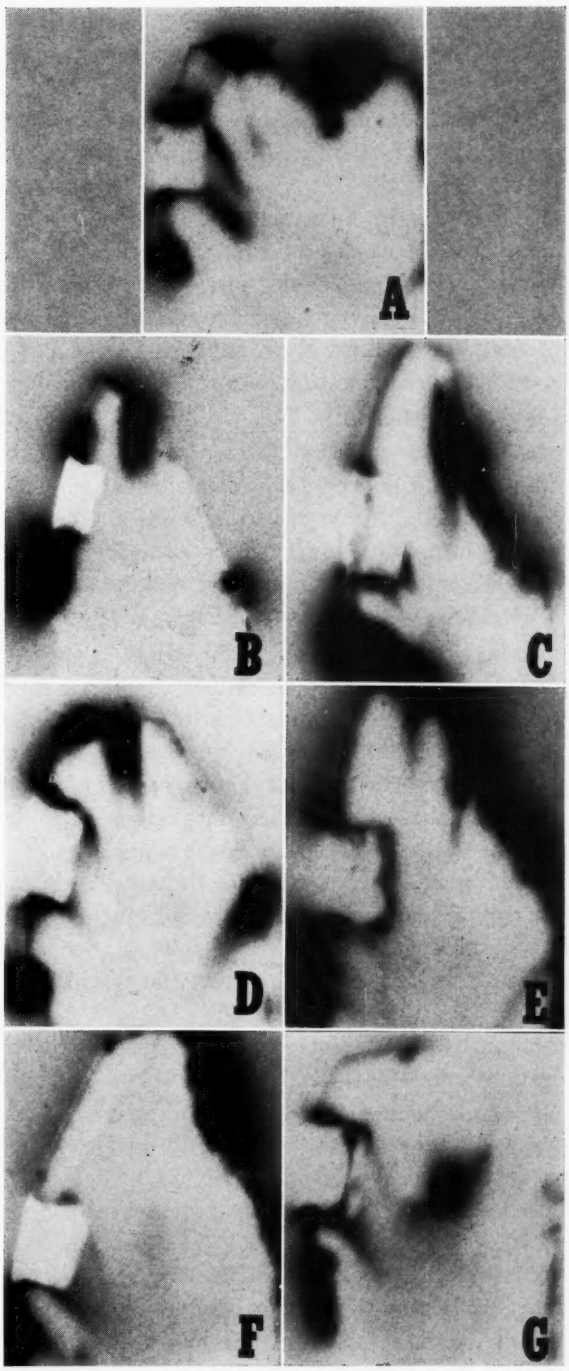

Fig. 7.—Autoradiographs of silver amalgam restorations immersed in Na^{22}. See Figs. 4 and 5 for data and description. Note that Na^{22} penetrates even through intact enamel and abraded dentine and produces a fuzzy autoradiograph.

leakage of newly placed silver amalgam restorations. This is less than occurs around acrylic resin and silicate cement restorations but considerably more than is seen in the autoradiographs of gold foil and gold inlay restorations.[10,11] This study emphasizes the need for an impermeable liner under every amalgam filling to prevent the penetration of salivary ions from passing through filling margins and into the underlying dentine and pulp.

Penetration of ions in vivo into dentine under an amalgam restoration is probably not as rapid or as prominent as occurs in vitro since sclerosis of the dentine makes this area impermeable. Secondary dentine formation also slows or stops ionic penetration into the pulp, giving good pulp protection. However, the dentist can help the pulp to protect itself against the wound in freshly cut dentine by using an impermeable liner under every amalgam restoration. The question then arises which liner or base will serve best.

Functions of an Ideal Liner or Base Under Amalgam.—Four main functions have been ascribed to an ideal liner: (1) thermal insulation, (2) galvanic insulation, (3) prevention of the penetration of mercury into the dentine and subsequent discoloration of the dentine, and (4) reduction of marginal penetration of ions around amalgam with diffusion into the underlying dentine and pulp.

Effectiveness of Various Liners and Bases.—Using four different ionic tracers, this study shows that the commonly used zinc phosphate cement base is of little value in reducing marginal or dentine penetration. Phillips, Schnell and Phillips[5,6] have shown that this material is not a galvanic insulator, and Silberkweit and associates[15] have shown that the acid of zinc phosphate cement is injurious to the pulp. Its only value appears to be as a thermal insulator. It is also felt that zinc phosphate cement as a base under amalgam etches the undersurface of the amalgam restoration in addition to increasing the permeability of the dentine.

The most effective liner under amalgam was the copal resin varnish (Copalite), because it limited marginal penetration of all radioisotopes to a superficial depth and thus eliminated dentine penetration completely. Under silicate cement, this liner has been shown to be ineffective in preventing acid penetration into the dentine and pulp tissue.[15,16]

In contrast, calcium hydroxide liners have been shown to be effective in preventing acid penetration from silicate and zinc phosphate cements.[17] Under amalgam restorations, these liners are only partially effective, since dentine penetration is prevented but marginal penetration is slightly increased because of the concentration of the isotopes in the lining substance. Phillips, Schnell, and Phillips[5,6] showed that calcium hydroxide liners and pastes are ineffective as galvanic insulators.

The polystyrene-ethylcellulose liner (Mizzy) was also found to be effective in blocking dentine penetration by the various isotopes, as well as slightly decreasing the penetration around the margins of silver amalgam restorations. However, it was not nearly as effective as the copal resin varnish.

Although zinc oxide–eugenol rates very high as a thermal and galvanic insulator, it is not as effective an ionic barrier, since it allowed penetration of ions into the underlying dentine.

SUMMARY

The purpose of this study was to test the influence of cavity liners, under class V silver amalgam restorations, on the penetration of radioactive tracers through the filling margins and the underlying dentine. Two hundred and thirty-four newly extracted human teeth were used in this study. Eight different liners and bases were tested in four different isotope solutions.

It was found that the films formed by a copal resin varnish and a polystyrene-ethylcellulose liner prevented dentine penetration of the isotopes via the filling margins and also decreased marginal penetration significantly. The calcium hydroxide liners completely blocked dentine penetration by the isotopes but tended to concentrate the radioactive solutions in the liner substance. Marginal penetration was slightly increased. Zinc oxide–eugenol bases decreased dentine penetration somewhat but did not decrease the degree of marginal penetration. Zinc phosphate cement *increased* dentine penetration markedly as well as penetration of negative ions into the amalgam substance. Marginal penetration also may have been slightly increased.

Under the conditions of this experiment, copal resin varnish, polystyrene-ethylcellulose liner, and calcium hydroxide liners were effective in preventing penetration of radioactive ions into the dentine and pulp; zinc oxide–eugenol and zinc phosphate cement bases were not.

CONCLUSION

This study emphasizes the need for scientific evaluation of clinical procedures using whatever scientific tools are available. The radioactive isotopes are a comparatively new tool that can be used to visualize and trace the diffusion of salivary ions in vitro and thus test the marginal integrity of filling materials in a manner never before possible.

Further evaluation of other liners and bases under amalgam and under silicate cement restorations is in progress.

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TEMPERATURE RESPONSE TO INCREASED ROTATIONAL SPEEDS

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THE TEMPERATURE in the pulp chamber must be maintained as close to normal as possible with increased rotational speeds and rapid removal of tooth structure. Air, water-air mixture, and water streams provide a variety of methods to control temperature. Although all are useful and effective, problems associated with cavity preparation are varied, and no one method of cooling is universally applicable. This is especially true when working indirectly on the upper dental arch where vision becomes a problem. The intelligent selection of a coolant to meet a particular situation will complement, rather than hinder, the operative procedure.

Uncertain conclusions have been reported relative to temperature changes in the pulp chamber with increased rotational speeds.[1-10] This is especially true within the range of the ultra high speed instruments. Reported temperature changes vary from a few degrees to several hundred.[3,5,9,10,12] These variations in temperature can be attributed to different speeds, loads, types of experimental equipment, in vivo or in vitro conditions, and method of placing and positioning the recording device. Some investigators[13] have reported that temperatures recorded in vital teeth were consistently lower than those in extracted teeth, while others[8] maintained there was no significant difference.

This study was undertaken to determine the temperature change within the pulp of teeth during clinical operative procedures while utilizing varying rotational speeds. The experimental program was carried out on vital teeth which were subsequently extracted for orthodontic or prosthodontic reasons.

METHODS

An iron constantan thermocouple connected to a sensitive galvanometer was used to measure the temperature change in the pulp (Fig. 1). The reported sources of error[14,15] when measuring short-term temperature variations are (1) the thermometric lag, (2) the lag of the measuring instrument, (3) the current leakage through connectors, (4) the size of the sensitive part of the thermocouple, and (5) the heat loss resulting from conduction through connecting wires. These factors were considered† and the recording device was calibrated with a mercury thermometer.

All cutting procedures were accomplished with the rubber dam in place. A thermocouple was wedged in the pulp chamber through a hole prepared at the gingival surface of the tooth with a No. 35 inverted cone bur (Fig. 2).

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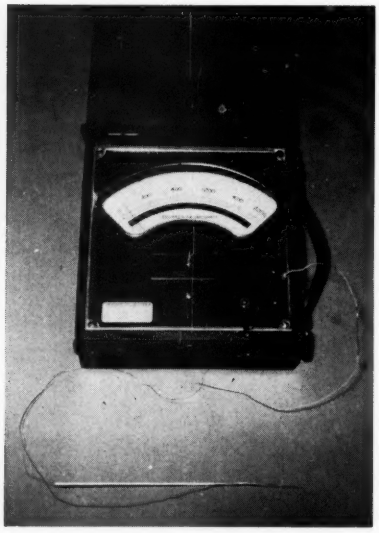

Fig. 1.—A thermocouple and galvanometer are used to measure temperature changes in the pulp.

A double rubber dam was used to eliminate error in temperature response by coolants entering through the hole in the tooth (Fig. 3). The thermocouple was placed in the tooth between the insulating dams.

One hundred and forty-seven cavity preparations were made. The test preparations included class I, class II, MOD, and class V cavities, crown preparations, and cutting through amalgam and gold restorations. Air alone and air-water spray were used as coolants. Attempts were made to generate as much heat as possible during all cutting procedures. More heat was produced than with normal operating procedures.

Fig. 2.

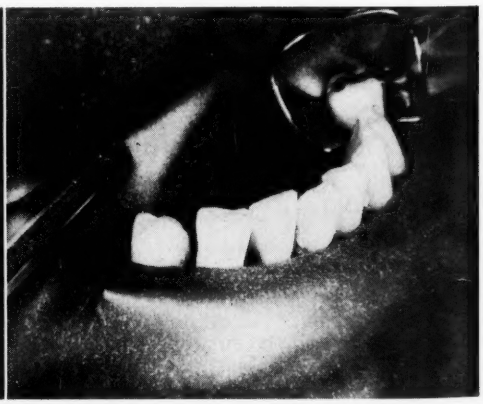

Fig. 3.

Fig. 2.—The thermocouple is in place in the pulp of the tooth. A single layer of rubber dam isolates the teeth.

Fig. 3.—The second layer of rubber dam is in place. The thermocouple is between the two layers of rubber dam.

RESULTS

The first series of tests was made at conventional speed with and without air coolant (Table I). The cavities were prepared by the generally accepted operative techniques with the rubber dam in place.

The operating time for each technique was the *same*. However, cavities cut at conventional speed were not completed to the same degree as those with which increased rotational speeds were employed.

A latent heat was apparent only in the preparations made at conventional speed with no coolant. The heat was eliminated by cooling with air at conventional speed.

The results of cutting procedures using a belt-driven instrument operating at 160,000 r.p.m. are seen in Table II. The preparations were made with ease, imperceptible vibration, and very light pressure. The temperature rise was consistently lower than the temperatures recorded at conventional speeds with no coolant.

TABLE I. CONVENTIONAL HANDPIECE (1,800 TO 10,000 R.P.M.)

SURFACE CUT	TEMPERATURE RISE (F.)		
	AVERAGE	MINIMUM	MAXIMUM
*No coolants**			
Class V preparation	+ 5.2°	+1°	+14°
MO:DO:MOD and occlusal preparations	+15.0°	+7°	+20°
Crown preparations	+22.0°	Cutting inefficient and traumatic	
Air coolant			
Class V and class II preparations	+ 1.0°	−5°	+ 4°

No. 557 and No. 37 burs. Average cutting time 30 seconds; minimum 15 seconds; maximum 90 seconds.

*Latent heat was apparent on these cuts.

The last series was accomplished with an air turbine operating at approximately 290,000 r.p.m. (Table III). Again, the cutting was done rapidly with imperceptible vibration and lighter pressure than that needed with the belt-driven instrument. Of great significance was a recorded temperature drop except when cutting through metal. This was in contrast to the temperature rise recorded in Tables I and II. The metals are good conductors, in contrast to enamel and dentine, and apparently retain the heat for conduction to the pulp chamber. By comparison, this temperature rise is small and insignificant.

Because of the extensive reports on air-water spray coolants,[1-10] this study was devoted principally to the cooling effectiveness of air. A series of tests was made using the air turbine with the air-water spray as a coolant. The air-water spray proved to be a slightly more effective coolant than air alone (Table III).

DISCUSSION

The rotating bur, especially at high speeds, generates high heat at the area of contact with the tooth structure. However, the low conductivity of the dentine and

TABLE II. BELT DRIVE (APPROXIMATELY 160,000 R.P.M.)

SURFACE CUT	TEMPERATURE RISE (F.)		
	AVERAGE	MINIMUM	MAXIMUM
Class V preparation	+4.0°	+2°	+10°
MO:DO:MOD and occlusal preparations	+6.7°	0°	+18°
Crown preparations	+5.7°	0°	+17°
Amalgam or gold	+6.3°	0°	+15°

No. 557, No. 57, and No. 171 fissure burs. Average cutting time 30 seconds; minimum 15 seconds; maximum 85 seconds.

the ability of the circulation of the pulp to absorb thermal change dissipates the heat conducted to the pulp chamber. Also, the coolant acting on the entire exposed crown of the tooth reduces its temperature, thereby counteracting the heat produced by the rotating cutting instrument.

It would seem logical to assume that the greatest heat dissipation is from the tooth surface rather than into the dentine, which is a poor conductor. The cooling effect of any of the coolants is an over-all temperature reduction of the entire crown rather than of just part of the tooth being cut. It would require a stream or spray of water under high pressure to pierce the air space around the bur revolving at ultra high speed.

Information is meager concerning the temperature the healthy or diseased pulp can withstand. Authorities[5-11] have reported that pulp tissue will readily tolerate

TABLE III. AIR TURBINE (APPROXIMATELY 290,000 R.P.M.)

SURFACE CUT	TEMPERATURE CHANGE (F.)		
	AVERAGE	MINIMUM	MAXIMUM
Air coolant			
Class V preparation	−4.3°	−1°	− 9°
MO:MOD:DO and occlusal preparations	−6.8°	0°	−17°
Crown preparations	−4.9°	−1°	−10°
Amalgam or gold	+3.0°	−3°	+11°
Air-water spray coolant			
Class V and class II preparations	−8.6°	−5°	−16°

No. 57 and No. 171 fissure burs. Average cutting time 30 seconds; minimum 15 seconds; maximum 90 seconds.

a temperature rise of approximately 30° to 40° F., although for how long a time is obscure. On the basis of the information presented in the tables, the temperature rise with the belt-driven instrument rotating at 160,000 r.p.m. is within these

limits. A temperature drop was recorded when operating the air turbine (Table III). The only exceptions were observed when cutting gold and amalgam, which are good conductors of heat. Even with these, the temperature is within normal limits.

CONCLUSIONS

This study indicates that increased rotational speeds are not traumatic to the pulp from the standpoint of temperature rise. However, these higher speeds may be traumatic from other aspects such as vibration, noise, and dessication. These possibilities must be explored.

The various problems of cavity preparations, especially vision, dictate the use of a flexible cooling armamentarium. Air and air-water spray are both effective coolants and can be used to complement operative procedures.

This report has dealt with one phase of an investigation of the effects of increased rotational speeds. In addition to histologic studies, we must study clinical findings, roentgenograms, and vitality tests to properly evaluate the over-all effects of increased rotational speeds.

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DISTORTION OF IRREVERSIBLE HYDROCOLLOID AND MERCAPTAN RUBBER-BASE IMPRESSIONS

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DIMENSIONAL ACCURACY OF IMPRESSIONS is one of the most important factors in the production of indirect working casts for inlays and other fixed prostheses. Elastic impression materials such as alginate (irreversible hydrocolloid) or mercaptan rubber-base compounds are supported by a tray. This support results in variable distortion when the impression material expands or contracts.

Skinner and associates[1,2] reported that the accuracy of the irreversible hydrocolloid impressions is slightly superior to that of the reversible hydrocolloid impressions. Hollenback[3] found the same result and further warned that the mercaptan rubber-base impression shrank significantly with time.

Schwindling[4,5] reported that irreversible hydrocolloid impressions showed highly inconsistent duplications, while the rubber-base impressions duplicated in a highly consistent manner. Skinner[6] reported that a fixed partial denture constructed directly on the original die could be seated on a stone cast poured 8 weeks after the rubber-base impression was made. Rosenstiel,[8] Fairhurst and coauthors,[9] Sturdevant,[10] and others[11-13] also showed favorable results for the mercaptan rubber-base impression.

Miller[14] found a 0.04 to 0.17 per cent linear shrinkage of mercaptan rubber-base impressions in a free state during a period of 24 hours. Schnell and Phillips[15] found more shrinkage in the same amount of time when they measured dies poured in mercaptan rubber-base impressions held in tube trays.

A conclusive evaluation is difficult to establish from these reports since the experimental conditions did not always correspond to the clinical conditions. Impressions made under clinical conditions have the most practical value when determining the accuracy of casts or dies.

This article reports the influences of the following factors on the accuracy of the impression: (1) irreversible hydrocolloid impression fixation, (2) stone cast materials, (3) the effect of time on mercaptan rubber-base impressions, (4) the effect of thermal shrinkage of mercaptan rubber-base impressions, (5) the effect of restraining forces caused by the tray, and (6) the undercuts of adjacent teeth.

SPECIMEN PREPARATION

The materials used are listed in Table I. Alginates 1 and 2 in the table were irreversible hydrocolloid powders mixed with water. Alginate 3 was an irreversible

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hydrocolloid of the paste type mixed with plaster. Mercaptans 1 and 2 were mercaptan rubber-base impression materials which consisted of two pastes, one the base and the other an accelerator. Hydrocals 1, 2, and 3 were quick-setting artificial stones of the Hydrocal type, and Densite 1 was a hard stone of the Densite type.

IRREVERSIBLE HYDROCOLLOID IMPRESSIONS

A thin coating of petroleum jelly was applied to the original die as a separating medium for irreversible hydrocolloid impressions. The material was mixed by rotating a spatula 200 times in a rubber bowl for 1 minute. One minute was allowed to fill the tray, and then the material was impressed on the original die. The impression was removed after 5 minutes with one sudden motion and immediately fixed in either 0.5 to 2 per cent $ZnSO_4$ or 0.1N H_2SO_4 solution from 30 to 60 seconds. Some impressions were removed at mouth temperature and others at room temperature.

During the 30 second period of fixing time, the artificial stone was mixed and then poured in the impression. The excess fixing solution was removed by one or two light shakes, leaving a glossy wet film on the impression surface. The cast was removed from the impression after being stored in a humidor for 1 hour. The cast was measured 24 hours after being poured. Only Hydrocal artificial stones were used in irreversible hydrocolloid impressions, since Densite stones produce poor cast surfaces in these materials.[16]

TABLE I. MATERIALS TESTED

MATERIALS	LOCATION OF MANUFACTURER	CHARACTERISTIC	WATER/POWDER MIXING RATIO	SETTING EXPANSION (%)
Alginate 1	Japan	Powder mixed with water	2.5*	
Alginate 2	United States	Powder mixed with water	2.5*	
Alginate 3	Japan	Paste mixed with plaster	0.5†	
Mercaptan 1	Japan	Base and accelerator pastes	Same length	
Mercaptan 2	United States	Base and accelerator pastes	Same length	
Hydrocal 1	Japan	Powder mixed with water	0.30*	0.54
Hydrocal 2	Japan	Powder mixed with water	0.32*	0.52
Hydrocal 3	United States	Powder mixed with water	0.30*	0.19
Densite 1	Japan	Powder mixed with water	0.23*	0.06

*Ratio in weight.
†Ratio in volume.

RUBBER-BASE IMPRESSIONS

A special separating medium was used for mercaptan rubber-base impressions. The agent was made by mixing two parts of an alginate solution (as used for separating dentures from the mold) with one part of a surface tension–reducing agent and three parts water. The separating medium was coated and dried on the original dies before the impression was made.

Mercaptan rubber-base material was mixed thoroughly on a paper pad for 60 seconds, loaded in an adhesive-lined tray in the next 60 seconds, and seated on the original die. Some impressions were made at mouth temperature, while others were made at room temperature. The impressions were removed after 13 minutes with one sudden motion (13 minutes was the minimal time to secure consistent results at room temperature). The artificial stone was mixed for 30 seconds in a rubber bowl with a spatula and vibrated into the impressions after varying time lapses. The cast was removed from the impression 1 hour after pouring and was measured after 24 hours.

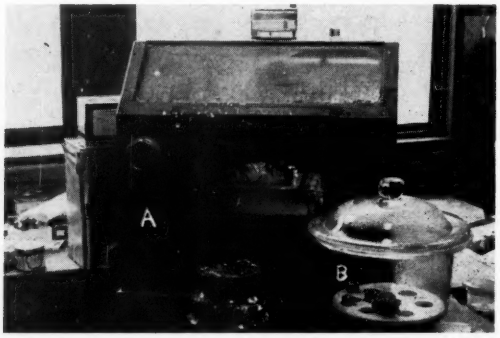

Fig. 1.—Impressions were stored in either *(A)* a thermostatic box or *(B)* a humidor.

TEMPERATURE AND HUMIDITY

The temperature and humidity were controlled carefully, since these factors have a significant effect on the accuracy of impressions or artificial stone casts.

The impressions were usually made on the original die and stored in a thermostatic box at 37° C. The temperature and saturated humidity in this box represented mouth conditions. Other impressions were stored in a humidor at room temperature (Fig. 1).

Impression materials and artificial stones were stored and mixed at room temperature. The room remained at either 17° or 27° C. and at 88 to 94 per cent relative humidity by adjusting a stove and a water bowl.

MEASUREMENT WITH INDIVIDUAL DIES AND TUBE TRAYS

Fusayama[17] used a pair of original dies for comparing the outside and inside dimensional changes of stone dies. By modification, an original die was devised so that one die could be used to measure both outside and inside dimensional changes (Figs. 2 and 3).

An intracoronal cavity preparation was cut into the top central part of the original die *(A)*. The diameter of the die was 10 mm., while the diameter of the circular cavity preparation was 6 mm. A small hole was drilled through the center of the die along the long axis to release the vacuum caused by removal of the im-

pression. The bottom of the cavity preparation was covered with tissue paper to prevent the impression material from penetrating the holes.

The trays were designed to produce a 2.2 to 3 mm. thickness of impression material. The tray for irreversible hydrocolloid impressions (D_1) was perforated, while the one for mercaptan rubber-base impressions (D_2) was not.

The expansion of the artificial stone cast which duplicated the cavity preparation raised the brass ring (*B*) on the outside, while the brass insert (*C*) on the inside was depressed. This occurred because of the way the ring and insert were tapered. The ratio of the amount of taper was 1:10 so that the distance the ring was raised or the insert depressed multiplied stone expansion 10 times. The distances were measured with a dial indicator calibrated to 0.01 mm. Expansion was calculated as shown by x and y in Fig. 4.

When the impression was made at mouth temperature and the artificial stone die was measured at room temperature, the measurement error caused by the thermal shrinkage of the original die or brass fittings was eliminated by calculating from the 0.002 per cent per 1° C. thermal shrinkage of brass.[18]

MEASUREMENT OF CASTS MADE WITH A TROUGH TRAY

A trough tray is generally used for making impressions of teeth in the mouth. The individual original dies were lined up on a base and trough experimental trays were designed to investigate the distortion effect of this type of tray (Fig. 5).

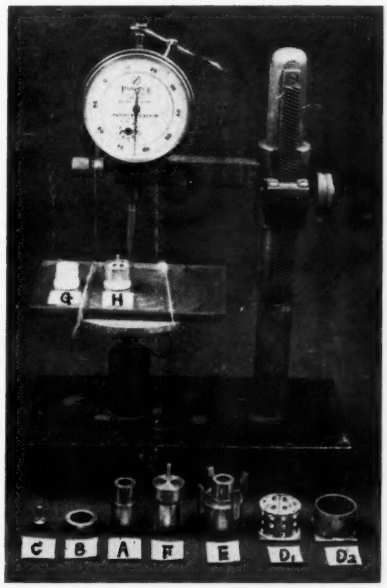

Fig. 2.—The comparative measuring apparatus is used to test the accuracy of indirect dies from the outside and inside: *(A)* the original die; *(B)* the brass ring; *(C)* the brass insert; *(D_1)* the tube tray for holding irreversible hydrocolloid impressions; *(D_2)* the tube tray for holding mercaptan rubber-base impressions; *(E)* the original die on a base ready for the impression; *(F)* the original die with brass ring and insert; *(G)* the resultant stone die; *(H)* the stone die with the brass ring and insert ready for measurement.

Lining up the dies on one block prevented a rotational movement during removal of the impressions. For this reason, the increased vacuum in the internal cavity preparation made the removal of impressions quite difficult. Because of the distortion possibility of this tension, the internal cavity preparation was filled with wax. A small hole penetrated the center of the wax to break the suction. The hole was covered with tissue paper before the impression material was applied. As a result, only the expansion from the outside could be measured for this test.

The resultant cast was sectioned into five individual dies. The two outer dies were omitted, and the other central three dies were used for measurement. The outside dimensional change was measured in two directions, buccolingually and mesiodistally, and at three heights, 2, 4, and 6 mm. from the top of the die.

The gauge for measuring discordance (or discrepancy)[17] was used to determine dimensional changes. At first, the original die was placed between the fixed and movable parts of the gauge, and a reference line was cut through the fixed and movable portions. Then a resultant artificial stone die was placed, and the discrepancy of the reference line indicating the dimensional change of the stone die was read under a measuring microscope calibrated to 1 μ.

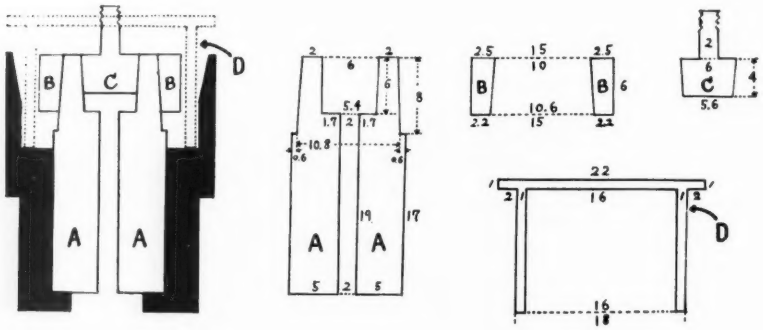

Fig. 3.—The design of the comparative measuring apparatus: *(A)* the original die; *(B)* the brass ring; *(C)* the brass insert; *(D)* the tray; the base is in black.

Three gauges were used for measuring at three heights (Fig. 6). The original die had tapered side walls. Therefore, the walls were touched with the top edges of the gauges having three different heights when the die was placed with the top surface down. The change in diameter of the artificial stone dies was measured at these heights.

MEASUREMENT OF DISTORTION

Clinically, the residual distortion of elastic materials produced by the undercuts of adjacent teeth upon removal of the impression also causes distortion.

The brass die used to measure distortion was placed on a base between two extracted teeth with distinct undercuts (Fig. 7). The distances from the base of

the die to the cervical margins of the bicuspid and the molar were, respectively, 35 and 37 per cent longer than the distances from the die to the contact points of the respective teeth on a horizontal plane. The inside cavity was filled with wax.

The impression was made with a perforated tray[19] used for the irreversible hydrocolloid indirect technique. The open ends were closed with sheet wax. The dimensional change was measured in two directions and at three heights of the central die after the die part of the stone cast was cut out. The discrepancy measurement instrument was used as in the previous experiment.

DISCUSSION OF MEASUREMENT READINGS

Two factors govern the accuracy of indirect casts: (1) dimensional change of impressions and (2) setting expansion of artificial stones.

The shrinkage or expansion of an elastic impression held by a tray always produces distortion. When an impression material contracts in a tube tray, the dimensions of the artificial stone die increase outside and decrease inside since the outside part of the impression material shrinks toward the tray walls and the inside

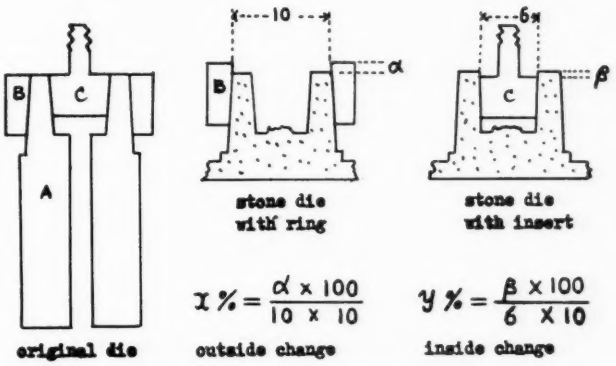

Fig. 4.—The expansion is calculated by percentage after the changes are measured with a dial indicator.

impression core shrinks toward the center. When an impression material contracts in a trough tray, the cast widens buccolingually since the impression is drawn to the two side walls of the tray. Expansion of impression material causes distortion in the opposite direction.

Thus, the dimensional changes of elastic impression materials are always undesirable and should be minimized. Such distortion is indicated by the difference of dimensional changes between the outside and inside measurements of the artificial stone dies in tube trays and by that between the buccolingual and the mesiodistal measurements of the stone dies in the trough tray. The less the shrinkage of the impression material, the less such a difference and the less the distortion.

On the other hand, the setting expansion of an artificial stone poured in an elastic impression is not always undesirable. A comparatively large setting ex-

pansion of stone is sometimes desirable to compensate for the casting shrinkage of metal. A possible expansion-contraction formula for a successful cast crown was calculated by Fusayama[20] with an experimental investment:

Expansion of indirect die	+0.1%
Expansion of investment	+2.0%
Shrinkage of gold alloy	−2.0%
Net change	+0.1%
Required space for cement	+0.1~0.5%

However, the total expansion of recommended cristobalite investments is about 1.6 per cent when the hygroscopic effect is eliminated by using a dry asbestos lining.[21] So the present optimum expansion-contraction formula for cast crowns may be:

Expansion of indirect die	+0.5%
Expansion of investment	+1.6%
Shrinkage of gold alloy	−2.0%
Net change	+0.1%
Required space for cement	+0.1~0.5%

Thus, the amount of dimensional change of an artificial stone die cannot be directly evaluated unless a given investment expansion and metal shrinkage are considered. Therefore, only the distortion shown by comparisons of either various sections or directions of stone dies were used to evaluate impression accuracy in this study.

RESULTS AND CONSIDERATION

The dimensional change figures in Tables II through VII represent the means of ten to twenty measurements for each group. The figures in parentheses indicate the standard deviations of the groups.

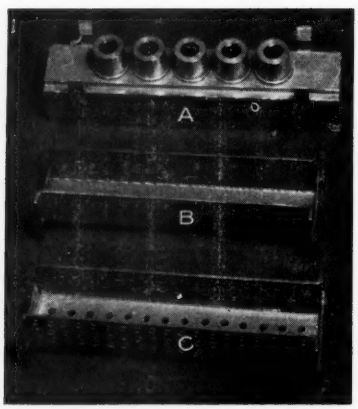

Fig. 5.—Impressions are made in trough trays to determine the effect of this type of tray in distortion: *(A)* the lined-up dies; *(B)* the tray for mercaptan rubber-base impressions; *(C)* the tray for irreversible hydrocolloid impressions.

INFLUENCE OF IRREVERSIBLE HYDROCOLLOID FIXATION

The influence of fixing conditions on the dimensions of irreversible hydrocolloid (alginate 1) impressions was investigated by comparing the outside and inside dimensional changes of the Hydrocal 1 dies with the individual original dies and tube trays. Results are compared in Table II. The outside dimensional changes

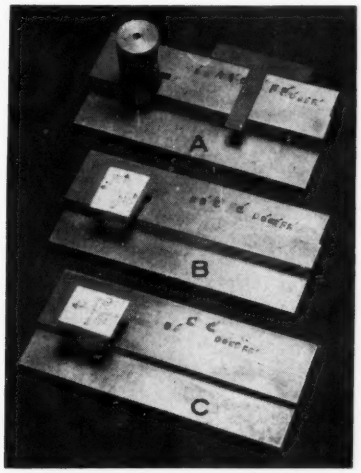

Fig. 6.—Discrepancy-measuring instruments are used to measure the dimensional changes of the dies: *(A)* the original die is placed on the 6 mm. level measuring instrument for cutting a reference line; *(B)* a stone die is placed on the 4 mm. level measuring instrument for mesiodistal measurement; *(C)* a stone die is placed on the 2 mm. level measuring instrument for a buccolingual measurement.

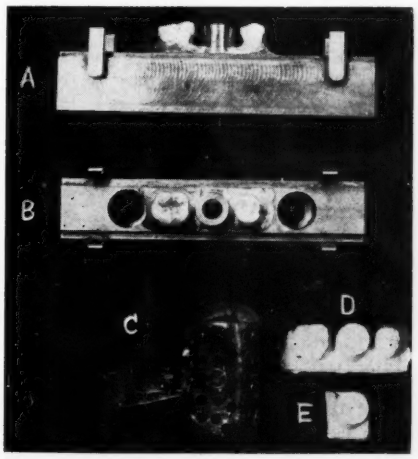

Fig. 7.—The experimental equipment necessary for measuring the distortion caused by undercuts of adjacent teeth: *(A)* front view of the model; *(B)* top view; *(C)* the impression tray; *(D)* the stone cast; *(E)* an isolated stone die prepared for measurement.

were greater than the inside changes. The difference between the outside and inside dimensional changes indicates the degree of distortion resulting from the shrinkage of the irreversible hydrocolloid impression material.

Increased concentration of the fixing solution or increased fixing time increased the outside dimensions, decreased the inside dimensions, and thus increased the irreversible hydrocolloid shrinkage, or distortion. Fixing for 30 seconds in a 0.5 to 1 per cent $ZnSO_4$ solution seems ideal since it also produced the best cast surface.[16]

Yamaga* suggested 0.1N H_2SO_4 solution as an effective fixing solution. It also produced a good cast surface but resulted in greater irreversible hydrocolloid shrinkage, even in 30 seconds.

VARIOUS STONES IN IRREVERSIBLE HYDROCOLLOID IMPRESSIONS

Impressions of the individual original dies were made using irreversible hydrocolloid of various brands in tube trays. The impressions were fixed immediately in a 1 per cent $ZnSO_4$ solution and poured with various artificial stones. Dimensional changes of the stone dies are compared in Table III.

TABLE II. INFLUENCE OF FIXING CONDITIONS OF ALGINATE 1 IMPRESSIONS ON THE DIMENSIONAL CHANGE OF HYDROCAL 1 DIES

FIXING CONDITIONS			DIMENSIONAL CHANGE OF DIES (%) (±S.D.)		DISTORTION (DIFFERENCE) (%)
MEDIUM	CONCENTRATION	TIME (SEC.)	OUTSIDE	INSIDE	
$ZnSO_4$	0.5%	30	+0.56 (±0.03)	+0.38 (±0.04)	0.18
		60	+0.61 (±0.04)	+0.35 (±0.04)	0.26
	1.0%	30	+0.64 (±0.04)	+0.36 (±0.04)	0.28
		60	+0.65 (±0.06)	+0.25 (±0.06)	0.40
	2.0%	30	+0.65 (±0.05)	+0.25 (±0.05)	0.40
		60	+0.70 (±0.04)	+0.20 (±0.03)	0.50
H_2SO_4	0.1N	30	+0.71 (±0.03)	+0.22 (±0.04)	0.49

Impressions were made at 37° C. and poured at 17° C.

Increasing the fixing time of the impressions increased the difference between the outside and inside measurements. Generally, no remarkable difference was found between different brands of irreversible hydrocolloids or Hydrocals. However, a significant increase in distortion was observed with Hydrocal 3, especially in combination with alginate 1, probably because of the retardation of rough cast surfaces.[16] Generally speaking, an indirect cast with a poor surface is also dimensionally inaccurate because such a surface decreases the dimension of the stone die.

*R. Yamaga: Personal communication.

TABLE III. DIMENSIONAL CHANGES OF VARIOUS STONE DIES POURED IN ALGINATE IMPRESSIONS

IMPRESSION MADE	STONE POURED	FIXING TIME (SEC.)	DIMENSIONAL CHANGE OF DIES (%) (±S.D.)		DISTORTION (DIFFERENCE) (%)
			OUTSIDE	INSIDE	
Alginate 1	Hydrocal 1	30	+0.64 (±0.04)	+0.36 (±0.04)	0.28
		60	+0.65 (±0.06)	+0.25 (±0.06)	0.40
	Hydrocal 2	30	+0.65 (±0.05)	+0.27 (±0.06)	0.38
	Hydrocal 3	30	+0.49 (±0.04)	−0.17 (±0.12)	0.66
Alginate 2	Hydrocal 3	30	+0.40 (±0.03)	+0.12 (±0.03)	0.28
		60	+0.51 (±0.05)	+0.04 (±0.03)	0.47
	Hydrocal 1	30	+0.51 (±0.05)	+0.27 (±0.01)	0.24
Alginate 3	Hydrocal 1	30	+0.63 (±0.06)	+0.43 (±0.07)	0.20
		60	+0.61 (±0.05)	+0.31 (±0.07)	0.30

Impressions were made at 37° C., fixed in 1 per cent $ZnSO_4$, and cast at 17° C.

The least distortion was obtained when alginate 1 impressions were immediately fixed in a 1 per cent $ZnSO_4$ solution for 30 seconds and then poured with Hydrocal 1 as a standard irreversible hydrocolloid technique. This technique was used in the rest of this report.

EFFECT OF TIME ON DISTORTION OF MERCAPTAN RUBBER-BASE IMPRESSIONS

Mercaptan rubber-base impressions of the individual original die were poured with Densite 1 at various times after removal of the impressions. The dimensional changes of the casts are compared in Table IV.

TABLE IV. DISTORTION OF MERCAPTAN RUBBER-BASE IMPRESSIONS WITH TIME

IMPRESSION MADE	STONE POURED	TIME LAPSE BEFORE POURING	DIMENSIONAL CHANGE OF DIES (%) (± S.D.)		DISTORTION (DIFFERENCE) (%)
			OUTSIDE	INSIDE	
Mercaptan 1 at 37° C.	Densite 1 at 17° C.	None	+0.55 (±0.05)	−0.20 (±0.02)	0.75
		30 min.	+0.54 (±0.05)	−0.20 (±0.03)	0.74
		1 hr.	+0.55 (±0.06)	−0.23 (±0.04)	0.78
		2 hr.	+0.57 (±0.07)	−0.26 (±0.07)	0.83
		6 hr.	+0.80 (±0.06)	−0.36 (±0.06)	1.16
		1 day	+1.18 (±0.08)	−0.64 (±0.09)	1.82
		3 days	+1.63 (±0.19)	−0.93 (±0.13)	2.56
Mercaptan 2 at 37° C.	Densite 1 at 17° C.	None	+0.48 (±0.06)	−0.23 (±0.04)	0.71
		1 hr.	+0.60 (±0.07)	−0.29 (±0.04)	0.89
		1 day	+0.90 (±0.13)	−0.48 (±0.05)	1.38

The later the impressions were poured, the larger the outside dimensions and the smaller the inside dimensions. The difference was as great as 1.82 per cent with mercaptan 1 after 24 hours. However, the distortion increase was not significant during the first hour.

This result roughly corresponds to that reported by Schnell and Phillips.[15] However, the free linear shrinkage of mercaptan rubber-base materials determined by Miller, Hansen, and Dickson[14] was smaller than 0.17 per cent after 24 hours. One probable reason for such a discrepancy may be that the volume shrinkage in three dimensions was forced into one dimension since the tray walls confined the other two dimensions.

The irregularities of the impression surface produced by the development of bubbles in rubber might also exaggerate the apparent dimensional changes in this test (Fig. 8). Therefore, a rubber-base impression should not be stored for a long time before pouring the cast.

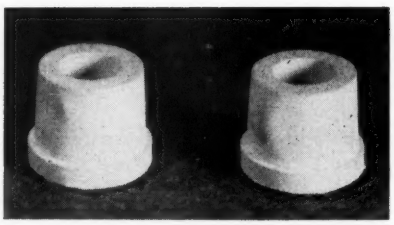

Fig. 8.—Extreme irregularity is produced in the surface of two dies by the development of bubbles in 3-hour-old mercaptan rubber-base impressions.

However, the difference between the outside and inside measurements was already more than 0.7 per cent even if the cast was poured immediately after removal of the impression. This distortion seems to have been caused by the thermal shrinkage of the mercaptan rubber-base impression, as will be discussed later.

THERMAL SHRINKAGE

The dimensional changes of artificial stone dies when the impressions were made and poured at various temperatures are compared in Table V. The thermal shrinkage of irreversible hydrocolloid from mouth to room temperature did not significantly distort the impressions when compared with impressions exposed to no temperature change.

Temperature difference significantly increased the distortion with mercaptan rubber-base impressions. The difference between the outside and inside dimensional changes was more than 0.7 per cent when the impression was made at 37° C. and poured at 17° C. However, the distortion was slight with no temperature change either at 17° or 37° C. Similar results were obtained with other artificial stones or mercaptan rubber-base materials. The thermal shrinkage of mercaptan rubber-base materials seemed much greater than that of irreversible hydrocolloid materials.

Thus, the distortion was less with irreversible hydrocolloid impressions than with mercaptan rubber-base impressions when the impressions were made at mouth temperature and poured at room temperature. The mercaptan rubber-base impressions were more accurate when poured in a thermostatic box at mouth temperature.

TABLE V. DISTORTION OF IMPRESSIONS WITH TEMPERATURE CHANGE

TAKING IMPRESSION		POURING STONE		DIMENSIONAL CHANGE OF DIES (%) (± S.D.)		DISTORTION (DIFFERENCE) (%)
MATERIAL	TEMPERATURE (C.)	TEMPERATURE (C.)	MATERIAL	OUTSIDE	INSIDE	
Alginate 1	17°	17°	Hydrocal 1	+0.48 (±0.04)	+0.28 (±0.05)	0.20
	37°	17°	Hydrocal 1	+0.64 (±0.04)	+0.36 (±0.04)	0.28
	17°	17°	Densite 1	+0.13 (±0.02)	+0.04 (±0.01)	0.09
	27°	17°	Densite 1	+0.36 (±0.05)	−0.15 (±0.06)	0.51
	37°	17°	Densite 1	+0.55 (±0.05)	−0.20 (±0.08)	0.75
	37°	37°	Densite 1	+0.05 (±0.02)	+0.02 (±0.03)	0.03
Mercaptan 1	17°	17°	Hydrocal 1	+0.53 (±0.05)	+0.29 (±0.04)	0.24
	37°	17°	Hydrocal 1	+0.93 (±0.06)	+0.06 (±0.02)	0.87
	17°	17°	Hydrocal 2	+0.45 (±0.04)	+0.24 (±0.04)	0.21
	37°	17°	Hydrocal 2	+0.82 (±0.07)	+0.06 (±0.03)	0.76
	17°	17°	Hydrocal 3	+0.20 (±0.01)	+0.09 (±0.02)	0.11
	37°	17°	Hydrocal 3	+0.47 (±0.02)	−0.25 (±0.04)	0.82
Mercaptan 2	17°	17°	Densite 1	+0.14 (±0.03)	+0.05 (±0.02)	0.09
	37°	17°	Densite 1	+0.48 (±0.06)	−0.23 (±0.04)	0.71
	17°	17°	Hydrocal 3	+0.21 (±0.06)	+0.07 (±0.02)	0.14
	37°	17°	Hydrocal 3	+0.71 (±0.04)	−0.27 (±0.04)	0.98

Impressions were poured immediately after fixing or removal.

LINED-UP DIES AND TROUGH TRAYS

In this experiment, the impression was held by a trough tray. The dimension of the artificial stone die increased buccolingually with the shrinkage of impression material. Therefore, the difference of dimensional changes between the buccolingual and mesiodistal widths indicated the extent of distortion caused by the impression material shrinkage.

Table VI compares the results when the impressions were made at mouth temperature and poured at room temperature. Again, the distortion was less with irreversible hydrocolloid than with mercaptan rubber-base material. This distortion seemed to be primarily from the greater thermal shrinkage, because the casts from mercaptan rubber-base impressions poured in a thermostatic box at mouth temperature were excellent (Table VI).

TABLE VI. DISTORTION OF IMPRESSIONS IN TROUGH TRAYS

IMPRESSION MADE	STONE POURED	DISTANCE FROM TOP OF DIE (MM.)	DIMENSIONAL CHANGE OF DIES (%) (±S.D.)		DISTORTION (DIFFERENCE) (%)
			BUCCOLINGUAL	MESIODISTAL	
Alginate 1 at 37° C.	Hydrocal 1 at 17° C.	2	+0.42 (±0.15)	+0.31 (±0.11)	0.11
		4	+0.43 (±0.09)	+0.38 (±0.09)	0.05
		6	+0.44 (±0.06)	+0.36 (±0.06)	0.08
Mercaptan 1 at 37° C.	Densite 1 at 17° C.	2	+0.15 (±0.08)	+0.03 (±0.03)	0.12
		4	+0.16 (±0.05)	+0.04 (±0.03)	0.12
		6	+0.19 (±0.07)	+0.03 (±0.04)	0.16
Mercaptan 1 at 37° C.	Densite 1 at 37° C.	2	+0.01 (±0.01)	0.00 (±0.02)	0.01
		4	+0.01 (±0.01)	−0.01 (±0.03)	0.02
		6	+0.01 (±0.04)	−0.01 (±0.01)	0.02

Impressions were poured immediately either after fixing or after removal.

ADJACENT TEETH WITH UNDERCUTS

The results of tests using adjacent teeth with undercuts are compared in Table VII. The difference between the buccolingual and mesiodistal dimensional changes of dies indicates the degree of distortion. The distortion effect of undercuts on irreversible hydrocolloid impressions seems negligible when compared with Table VI.

Mercaptan rubber-base impressions distorted more than irreversible hydrocolloid when the impressions were made at 37° C. and poured at 27° C. One of the reasons rubber-base material distorts more is thermal shrinkage. However, the effect of the undercuts is undeniable.

The distortion of mercaptan rubber-base impressions caused by the undercuts was less at 2 mm. below the top (near the occlusal surface) and more at 6 mm. below the top (near the cervical surface). This distortion caused by undercuts alone seemed almost corrected by storage for 1 hour before pouring (lower part of Table VII). However, the distortion was slightly increased by a wait of 1 hour when the thermal shrinkage was superimposed. The strain produced by the confined thermal shrinkage of mercaptan rubber-base impressions probably increased the distortion even after cooling.

American Dental Association Specification No. 11[22] determines the "permanent" set. This is the residual distortion of an elastic material compressed by a given load over a given period of time. Cresson[23] determined the residual distortion of an elastic material caused by a given amount of compression over a given period of time. Those tests are convenient for numerical comparison but may be misleading when comparing materials of different strength and structure such as irreversible hydrocolloid and rubber. Testing reaction to compressive forces for extended periods may also be misleading since the compression caused by removal of an impression from the mouth is very short lived. This is especially true of reversible and irreversible hydrocolloids, because hydrocolloids resist a sudden thrust but

are considerably less resistant to a continuous load.[22] The technique used in this experiment may be advantageous for more practical clinical reference, as far as concerns indirect inlay dies.

With this technique, the distortion was less with irreversible hydrocolloid impressions than with mercaptan rubber-base impressions when they were poured at room temperature. However, the mercaptan rubber-base impression was more accurate when poured in a thermostatic box at mouth temperature.

The distortion of Hydrocal 1 dies in alginate 1 impressions was 0.06 to 0.09 per cent when poured at room temperature. The accuracy of the irreversible hydrocolloid indirect technique seems clinically satisfactory even when poured at room temperature, since more than 500 inlays and crowns and more than 200 one piece–cast fixed partial dentures have been successfully seated in the mouth using Fusayama's technique.[16,21]

SUMMARY AND CONCLUSIONS

The factors that affect the dimensional accuracy of casts for the indirect technique were investigated using irreversible hydrocolloid and mercaptan rubber-base impression materials and Hydrocal and Densite artificial stones. The important findings were:

1. Fixing all irreversible hydrocolloids tested immediately in a 1 per cent $ZnSO_4$ solution for 30 seconds and then pouring with a Hydrocal artificial stone

TABLE VII. DISTORTION OF IMPRESSION PRODUCED BY UNDERCUTS IN ADJACENT TEETH

IMPRESSION MADE	STONE POURED	TIME LAPSE BEFORE POURING	DISTANCE FROM DIE TOP (MM.)	DIMENSIONAL CHANGE OF DIES (%) (± S.D.)		DISTORTION (DIFFERENCE) (%)
				BUCCOLINGUAL	MESIODISTAL	
Alginate 1 at 37° C.	Hydrocal 1 at 27° C.	After mixing	2	+0.39 (±0.10)	+0.46 (±0.10)	0.07
			4	+0.48 (±0.07)	+0.42 (±0.09)	0.06
			6	+0.53 (±0.06)	+0.44 (±0.08)	0.09
Mercaptan 1 at 37° C.	Hydrocal 1 at 27° C.	1 hr.	2	+0.69 (±0.06)	+0.31 (±0.04)	0.38
			4	+0.69 (±0.10)	+0.23 (±0.09)	0.46
			6	+0.60 (±0.04)	+0.21 (±0.05)	0.39
	Densite 1 at 27° C.	None	2	+0.06 (±0.13)	−0.13 (±0.03)	0.19
			4	+0.09 (±0.04)	−0.14 (±0.07)	0.23
			6	0.00 (±0.16)	−0.13 (±0.11)	0.13
		1 hr.	2	+0.17 (±0.05)	−0.19 (±0.04)	0.36
			4	+0.16 (±0.10)	−0.15 (±0.08)	0.31
			6	+0.07 (±0.05)	−0.20 (±0.05)	0.27
	Densite 1 at 37° C.	None	2	+0.01 (±0.01)	0.00 (±0.00)	0.01
			4	+0.06 (±0.10)	−0.05 (±0.07)	0.11
			6	+0.09 (±0.08)	−0.06 (±0.07)	0.15
		1 hr.	2	+0.01 (±0.01)	0.00 (±0.02)	0.01
			4	+0.01 (±0.05)	−0.01 (±0.03)	0.02
			6	−0.01 (±0.04)	−0.01 (±0.01)	0.00

seemed ideal. Either increased concentration or increased fixing time increased the contraction of irreversible hydrocolloid impression material.

2. Significant dimensional reduction of an artificial stone cast surface was observed with a combination of a stone and an irreversible hydrocolloid which produced a rough die surface.

3. The thermal shrinkage of mercaptan rubber-base material was much greater than that of irreversible hydrocolloid.

4. The distortion of mercaptan rubber-base impressions remarkably increased with storage time, but the distortion increase was not significant during the first hour.

5. The distortion effect of undercut adjacent teeth on impressions was negligible with irreversible hydrocolloid and slight with mercaptan.

6. The distortion of mercaptan rubber-base impressions caused by the undercuts was hardly evident at the end of 1 hour when poured at mouth temperature. However, the distortion increased with time when impressions confined in a tray were poured at room temperature.

7. Irreversible hydrocolloid impressions showed less distortion than mercaptan rubber-base impressions when made at mouth temperature and poured at room temperature. However, the distortion was least with mercaptan rubber-base impressions when poured in a thermostatic box at mouth temperature.

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PRACTICAL FACTORS IN BUILDING AND FIRING CHARACTERISTICS OF DENTAL PORCELAIN

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DENTAL PORCELAIN in thin, irregular, unreinforced sections is fragile and weakened and, under stress or tension, may be broken. A porcelain crown structure is minute in relation to the function it is expected to render.

It is not intended to imply here that porcelain restorations that will never fail can be constructed. However, if discriminatively employed and constructed in accordance with an understanding of practical factors, porcelain restorations give excellent service.

The results of this study are based on photoelastic tests and qualitative evaluation of about 400 defective and fractured porcelain jacket crowns. Wherever possible, the broken crowns were reconstructed and missing sections were reproduced. Stone casts were made of the cores for study purposes (Fig. 1).

SUBSTRUCTURE DESIGN

The influence of the shape of the preparation on the structural strength of the porcelain crown is essentially mechanical. Preparations are generally based on four tapering faces cut on the labial, lingual, mesial, and distal tooth surfaces. These faces converge axially in vertical line angles which may be rounded or left as sharp angles (Fig. 2).

In effect, the tapering configuration of a preparation or core is analogous to a wedge capable of dividing or splitting. This phenomenon is greatly multiplied by the presence of sharp line angles which are physically undesirable. Either alone or in combination with other contributing factors, sharp line angles, particularly on the lingual proximal surfaces, are responsible for most fractures.

The two types of breakage associated with porcelain crowns are initial and functional. Initial breakage occurs during preliminary clinical checking and adjustment or in cementing of the crowns. Barring accidents, this breakage is readily diagnosed as the result of internal impingement caused by discrepancies in the impression or the die or by the cementation technique.

Functional breakage is often less accountable and occurs after a period of usage. The cause is not always readily perceived or evaluated but unless corrected may lead to repeated remakes or unmerited abandonment in favor of possibly less desirable or esthetic media.

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Fig. 1.—The sections of a broken crown are assembled and a stone cast is poured for study.

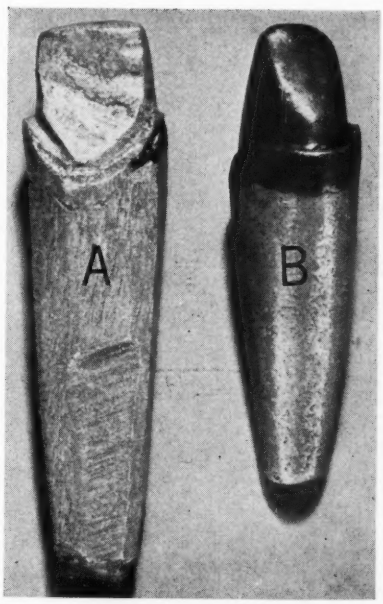

Fig. 2.—Clinical dies for porcelain crowns with *(A)* sharp line angles and *(B)* rounded line angles.

Sharp line angles on the preparation are intimately reproduced as internal indentations or lines of cleavage within the porcelain crown (Fig. 3). Upon final placement of the crown, the line angle prominences on the core are in direct apposition to the cleavage lines. Under masticatory loads on the crown, the cleavage lines and also any thin sections become focal points for stress concentrations which greatly weaken the restoration (Fig. 4). Ewing[1] and others have reported on the clinical aspects of this factor. The adverse effects of sharp line angles were noted by Walton and Leven[2] in photoelastic studies.

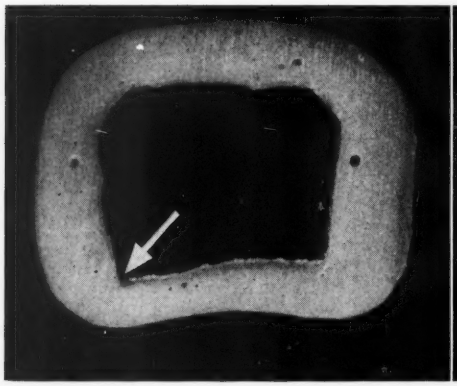

Fig. 3.

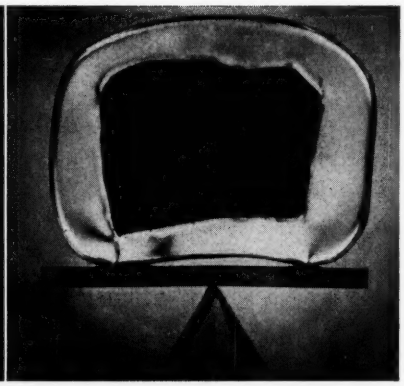

Fig. 4.

Fig. 3.—A horizontal cross section of a clinical porcelain crown shows sharp internal line angles on the lingual surface. The arrow indicates a potential line of cleavage.

Fig. 4.—A photoelastic reproduction of the cross-sectioned crown in Fig. 3. Weakening stress concentrations are apparent in the region of the sharp line angle as lingual pressure is applied.

Fractures in crowns provoked by sharp line angles occur at some point along the angular depression. The rupture usually pursues the cleavage line and travels across the thinnest section in a course of least resistance to another weak part (Fig. 5).

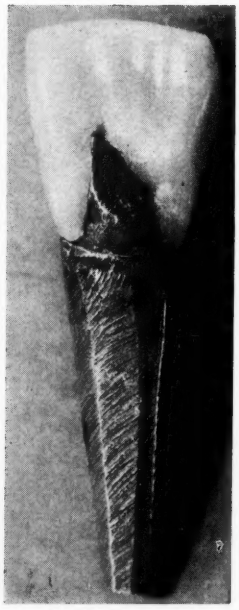

Fig. 5.—A crown shows a typical fracture at sharp lingual line angles.

The advantages and importance of well-rounded angles to the serviceability of porcelain restorations cannot be overemphasized. Roundness produces more even bulk in the crown and eliminates specific lines of cleavage. Therefore, stresses are distributed over a broader surface, which creates increased resistance to fracture.

SUBSTRUCTURE LENGTH

Mechanically, the ideal length of a preparation is two-thirds of the labial or buccal length of the crown. In longer preparations, the occluding surface of the crown is thin and weakened (Fig. 6), and fractures are usually characterized by shattering of the porcelain. Shade reproduction in anterior crowns is also difficult, since the long core protrudes offensively into the incisal translucent area and conspicuously shows through.

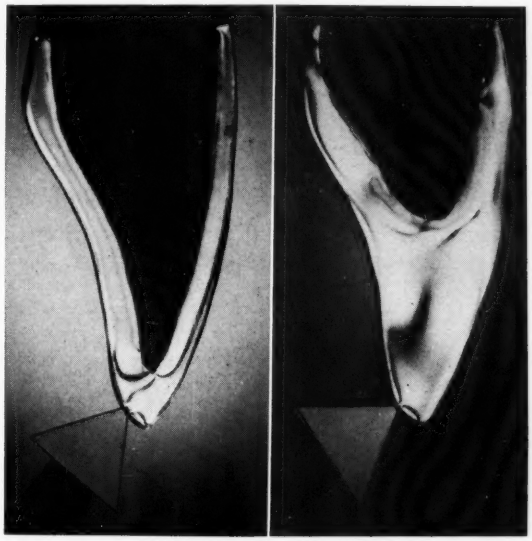

Fig. 6. Fig. 7.

Fig. 6.—Stresses are present in the incisal part of a crown supported on an excessively long preparation.

Fig. 7.—Stress fringes are present in the area of the incisal fulcrum of a short preparation, and stress concentrations are at the labial base of the crown.

A preparation length of much less than two-thirds intensifies the fulcrum action of the tip of the preparation, and the crown becomes an active lever. When a load is applied, reciprocal pressures at the base of the preparation create stress in the porcelain and may cause breakage (Fig. 7). Half-moon, crescent-shaped fractures at the gingival part of the crown are typical and occur on the plane of the crown diametrically opposed to the biting load (Fig. 8).

When the desired coronal length is lacking, it may be supplied with a corrective casting (Fig. 9).

SUBSTRUCTURE SHOULDER

A shoulder arrests the wedgelike action of a preparation that tends to cleave a porcelain crown (Figs. 10 and 11). A shoulder is much like the head of a carpenter's nail which prevents it from being driven any further into surrounding wood.

Porcelain cannot be feather edged on shoulderless preparations, for the porcelain chips away in thin sections and becomes a tissue irritant at the gingival junction of the crown. The minute chipped edges are jagged projections and, like other roughnesses, are conducive to tissue discoloration and progressive resorption of the gingivae. A shoulder ledge provides a flat surface on the gingival border of the crown which can be evenly and smoothly finished to a uniform slope confluent with the root. A crown is strengthened by a shoulder which provides additional thickness around the cervical margin.

MATRIX

The platinum foil matrix is essentially the material foundation upon which a porcelain restoration is built and which gives a faithful reproduction of the die. However, imperfections in the matrix are also reproduced within the crown, thus creating a potential weakness. When combined with other adverse factors, the existent weaknesses are augmented.

Occasionally, residual or excess metal is present during the fabrication of the platinum foil matrix by burnishing and swaging. The excess metal usually ac-

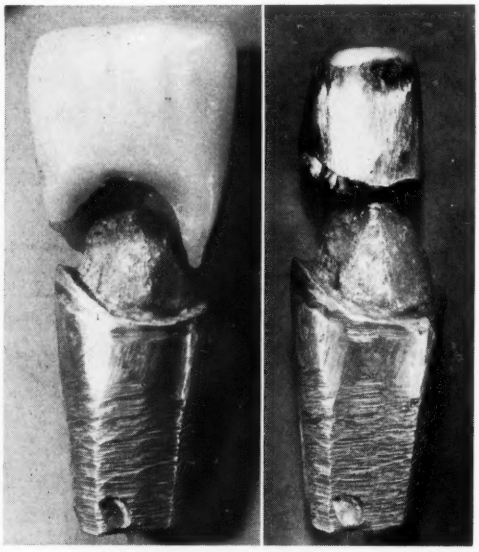

Fig. 8. Fig. 9.

Fig. 8.—A characteristic half-moon labial fracture at the gingival surface of the crown indicates that the preparation is too short.

Fig. 9.—A cast gold coping restores the correct coronal length of a short preparation.

cumulates vertically on or close to line angles on the die in the form of attenuate, projecting folds, or wrinkles because of the natural tendency of the residue to flow, under swaging pressure, toward edges and corners (Fig. 12).

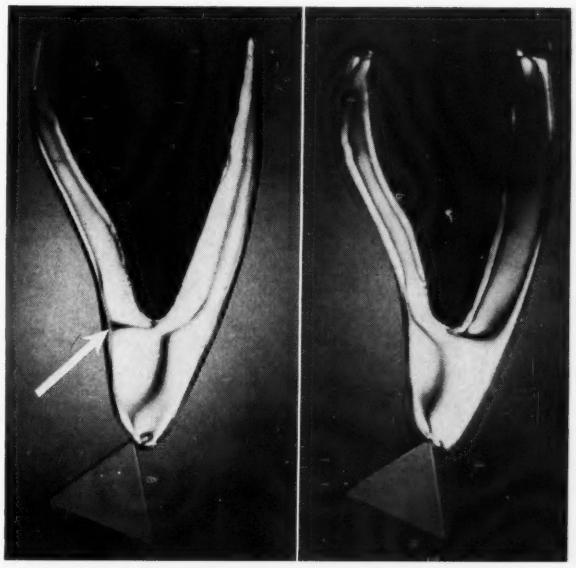

Fig. 10. Fig. 11.

Fig. 10.—Incisal loading on a shoulderless crown produces a severe stress band (arrow).
Fig. 11.—A full shoulder crown under load provides compression and well-distributed stresses which are favorable factors to strength.

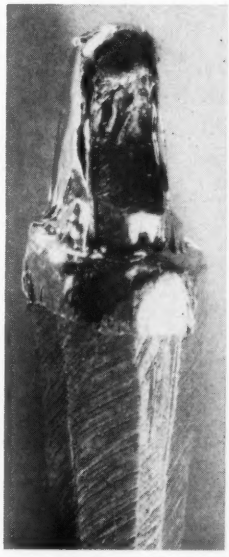

Fig. 12.—Platinum foil wrinkles gather on the line angles of a die during matrix swaging.

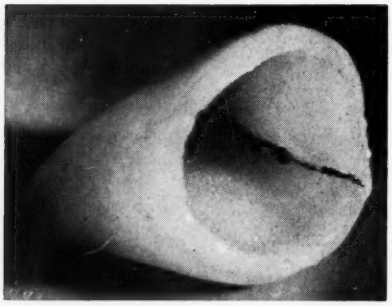

Fig. 13.—A platinum foil wrinkle is embedded in a finished crown.

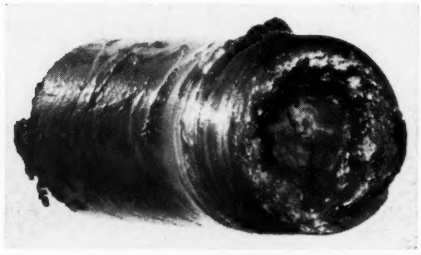

Fig. 14.—An encrusted water pipe can contaminate the tap water supply.

Unless burnished flat, the wrinkle projections are reproduced within the porcelain crown as defined lines of cleavage. Even on well-rounded preparations, these lines generally induce weakness. When the wrinkle projections are conjoined with existing sharp line angles of the core, the strength of the restoration is reduced to a seriously low level of functional tolerance.

The fold impressions can readily be observed on the inner surfaces of a finished crown. Occasionally, the metal folds are so excessive that they become embedded in the fired porcelain and remain permanently after the matrix is removed unless eliminated by grinding (Fig. 13).

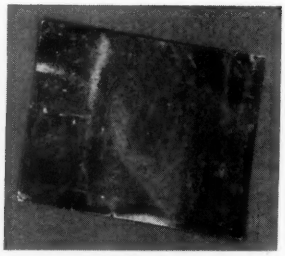

Fig. 15.—The cloudy area in the center of the platinum foil is typical contamination produced by the inner cone of gas flames.

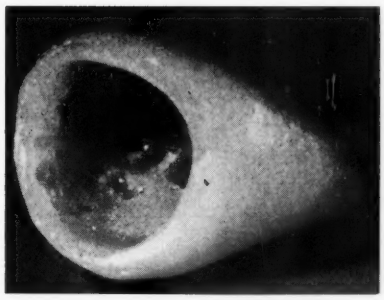

Fig. 16.—Excessive bubble formation is caused by platinum foil contamination.

CONTAMINATION

Contaminants consist of solids or gases, and they originate from a number of sources, some of which are latent or not readily perceived. Airborne dirt, grindings, soot, etc., are visible and with diligence can be prevented by exclusion or eliminated by manual removal.

Dissolved or suspended minerals in some tap water are usually latent and capable of contaminating dental porcelain. Sudden temperature fluctuations expand or contract building plumbing, and accumulated rust and mineral encrustations may dislodge into the stream of tap water and result in contamination (Fig. 14). Extreme discoloration and excessive porosity have been observed as a result of contaminated tap water on dental porcelain. Only distilled or demineralized water should be employed as the liquid vehicle for wetting porcelain powders.

Fig. 17.—The cervical discoloration is caused by platinum foil contamination.

Platinum matrix foil is a common source of latent contamination. Platinum has a natural affinity for a number of contaminating elements, especially in the presence of heat. During fabrication of the matrix, wax and oils are eliminated by flaming the matrix over a Bunsen burner. Minute traces of metals and other substances which might be present on the surface of the foil are chemically integrated and adsorbed during heating. The most prevalent contamination of the platinum is developed during prolonged flaming by the unburned gases of combustion in a yellow or poorly adjusted gas burner fire or in the gaseous inner cone of the flame (Fig. 15).

Adsorbed and integrated contaminations in the platinum matrix are released as gases by dissolution at elevated firing temperatures. These gases permeate the proximate porcelain mass, usually generating excessive porosity on the inner surface of the restoration immediately adjacent to the matrix. The porosity can often be seen as open voids randomized on the inner crown surface (Fig. 16). Large singular bubbles with an opening on the matrix side and redundant bubbles around the cervical border are occasionally formed.

General discoloration of the restoration is seldom apparent as a result of foil contamination, except that the cervical border is sometimes invested with a green or brown tint (Fig. 17). This color is usually caused by a soiled metal die, particularly at the shoulder. The condition can be readily corrected by scrubbing the die with a solvent such as chloroform prior to foil adaption.

The most positive method of eliminating platinum foil matrix contamination is accomplished by degassing. One or more completed empty matrices supported on a firing tray are fired in a porcelain furnace to a temperature slightly higher than the final glaze temperature as a preliminary step. The furnace temperature should be at least 200° F. lower than the final glaze temperature at the time of insertion. The rate of temperature increase is not important, and a hold period of a few seconds at the temperature peak is sufficient. This treatment dispels the offensive gases, and the density of the restorations is visably improved.

POROSITY

Porosity in air-fired porcelain is defined in part as interstitial spaces and is also variously termed voids, bubbles, blebs, and vesicular structure.[3] The ceramist prefers to classify porosity into two categories: (1) normal or included and (2) excessive or incurred.

Normal porosity consists of air and gases which become unavoidably entrapped in the interstices of porcelain powders during the mechanics of condensation and firing. This porosity is fine in texture and has been accepted for many years as an inherent factor in the characteristics of porcelain restorations.

Inadequate manual condensation, manipulation, contamination, and overfiring are the principal causes of excessive porosity and enlarged bubbles. Unfortunately, the conspicuous presence of incurred porosity is seldom apparent until the restoration is in a final stage.

Porosity affects the strength of porcelain in proportion to occurrence by exerting a weakening influence and creating zones of stress concentration and

pockets of low fracture resistance. Excessive porosity and large bubbles affect the porcelain strength somewhat more than the normal or included type. The edges of broken segments occasionally exhibit excessive or large pores which presumably were a significant factor in the structural failure (Fig. 18). The strength of the porcelain structure is further depreciated when porosity is associated with other weakness factors.

Fig. 18.—A fracture caused by sharp line angles coexists with large bubbles on the broken edges.

DENSITY

Manual condensation is essentially the maximum possible elimination of interstitial spaces in the powdered porcelain mass.[3,4] The grain sizes and quantity provide a limiting factor whereby all the spaces cannot be removed. The spaces are consequently sealed into the porcelain by vitrification and affect density.

The vacuum firing process completely eliminates normal air cells by allowing condensation to continue during firing without hindrance of entrapped air or gases. Vacuum-fired porcelain is extremely dense and free of porosity and provides many superior advantages in porcelain restorations. Vines and Semmelman[5] have reported the advantages of increased density in artificial teeth.

Inasmuch as porosity constitutes a weakening factor, it is reasonable to conclude that elimination of porosity promotes increased strength. Various commercial dental laboratories estimated gross percentage of breakage at 2 to 7 per cent in air-fired porcelain and 0.5 per cent or less in vacuum-fired porcelain. Since porosity is only one of the possible adverse variables in a restoration, it is notable that the elimination of this factor alone exercises a marked influence on strength.

FIRING

The type of porcelain, condensation density, age of the furnace muffle, fluctuating line current, and other factors influence a firing program. After a preliminary dehydration followed by a slow 1,500° F. burnout, the usual operating schedule is an increase in temperature of 50° to 100° F. per minute to the desired fusing point.

The extent of vitrification and consequent effect on the porcelain are important. Correctly vitrified porcelain is the result of arrested firing. Overfiring seriously affects the strength characteristics of the porcelain by developing pronounced brittleness and, thus, increasing fragility. Shade, translucency, and form are also undesirably altered or destroyed, and porosity is enlarged.

Dental ceramic material should be fired only in porcelain furnaces. Other furnaces such as inlay burnout types can produce discoloration and black specks in the porcelain.

SUMMARY

Some of the major practical factors that adversely affect the characteristics of porcelain restorations have been discussed.

Careful technique and execution are mandatory in porcelain restorations to avoid weakening factors which may result in premature fracture. A combination of various weakening factors further undermines the structure.

The esthetically ideal appearance of a personalized porcelain restoration is valueless if the restoration is not functionally sound.

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NUTRITION

GERODONTOLOGIC ASPECTS OF DIET AND NUTRITION

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INCREASED LIFE SPAN has altered the population so that 1 person out of 3 is 45 years of age or more. One out of 10 men and women is past the age of 65 years. With the aging process, changes in metabolism, vitality of cells, glandular balance, and dietary patterns occur commonly. The purpose of this article is to discuss nutrition and its effect upon the dental health of people in the older age segment of the population.

DIET AND NUTRITION

Diet concerns the variety and amount of food that is eaten. Nutrition is the process of providing proper food elements for maintenance of health and growth. Diet is important, but nutrition is more important because it includes digestion, absorption, assimilation, and actual utilization of the nutrients by the cells of the body. A proper diet must be followed if the individual is to be well nourished.

The foods which constitute a correct diet for one person may not provide adequate nutrition for another, because of the various ways the body may function. Therefore, the diet of every person must take into account that individual's physical system so that proper nutrition is derived from utilization and assimilation of nutrients.

DENTAL NUTRITION

Essential nutrients for good dental health are carbohydrates, fats, proteins, minerals, vitamins, and water. The body not only must utilize these nutrients, but should have them in proper proportions. Good dental health from a nutritional standpoint does not vary from good physical health.

Sometimes diets in magazines are completely unrealistic. One such article proposed a caries-preventing diet that included a cup of cream daily.[1] This diet admittedly would reduce cariogenic activity, but it would greatly increase the fat and cholesterol intake. The best dental health also would not be forthcoming from such nutrition. This diet is an extreme one and shows why one must not lose the proper perspective of diet and nutrition.

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USE OF NUTRIENTS

Carbohydrates are burned chiefly to form body energy. If a diet has more carbohydrates than necessary, the carbohydrates are changed and stored as fat. Fat in the diet provides some energy, while a portion may be stored. Stored fats may break down if the body draws on reserves for nutrition. Fat can be converted back into carbohydrates which the body utilizes for nutrition. However, the body does utilize carbohydrates more efficiently than fats.

Protein is utilized for building and repairing of protein tissue. Energy may also be derived from protein, but excessive quantities are stored as fat. An excessive quantity of fat, carbohydrate, or protein will appear as body-stored fats. Proteins are also necessary in the formation of hormones and enzymes.

Many minerals are needed to keep the body functioning properly. Phosphorus is found in all tissues. Calcium is important in bone formation in early stages of development, and it has many roles throughout life. Iron is another mineral that is necessary, as are many others.

In addition, vitamins are of great importance. From the dental standpoint, more clinical signs of avitaminosis can be seen than signs of deficiency in other nutrients. Vitamins are organic catalysts, essential to proper nutrition.

The dental problems that nutrition affects in older people are caries, disease of gums, of supporting tissues, and of oral soft tissues, and response to oral surgery and to prosthetic restorations.

CARIES

Caries activity can be increased or decreased in the older person by attention to the nutritional standard. Decrease in carbohydrate intake helps reduce it.

Rats were fed carbohydrates by a tube with no carious activity being demonstrated,[2] while the same diet fed by mouth resulted in caries for littermates. Carbohydrates were shown to be one of the chief nutrients causing decay, since a carbohydrate-free diet produced no carious lesions when fed to rats.[3] If the complete diet was taken by tube except for carbohydrates, fed by mouth, carious lesions occurred at a rapid rate.[4]

These facts provide experimental evidence that carbohydrates are cariogenic agents and should be restricted to a minimum for a good dental health diet. However, this creates a problem for older people of limited economic means; because of the relative inexpensiveness of carbohydrates, they often constitute a large part of the diet.

NUTRITIONAL DISEASE

Diseases of the gums and supporting tissues can be caused by nutritional disorders entirely, partially, or not at all. Possible contributory local factors must be evaluated and the nutritional aspects of such disorders considered. If these conditions are related to faulty nutrition, the diet must be corrected of any deficiency in nutrient minerals or vitamins. Actually, diagnostic symptoms of vitamin and mineral deficiencies appear frequently in the oral cavity. The oral disorders that occur are generally of long standing and do not develop until the person has suffered from an avitaminosis for a long time.

Vitamin A is a fat soluble vitamin necessary for the maintenance of the structure and functions of epithelial and glandular tissue. A long-standing vitamin A deficiency may cause hyperplasia of the gums as well as generalized gingivitis.

Vitamin B complex is broken down into many different B vitamins. B_1 or thiamine deficiency generally causes changes in the tongue and gingivae. The gingival tissue loses its characteristic stippling, and the tissue assumes a deep rose color. Often the tongue and the fungiform papillae become enlarged and hyperemic.

Vitamin B_2 or riboflavin deficiency manifests itself by a typical clinical picture. The tongue seems granular, and the fungiform papillae have a mushroomed appearance. Mild inflammation of the lips occurs and progresses until the vermilion borders may desquamate. The border becomes reddened and often crusted from hemorrhage. Angular cheilosis results in an oral lesion extending a few millimeters toward the cheek from the angle of the mouth. The lesion usually is moist and may become secondarily infected. Therefore, bacterial infection is often suspected as the cause rather than the existing nutritional deficiency. Angular cheilosis may result from a dental prosthesis which causes the mouth to be closed too far. This feature must be differentiated accurately.

Nicotinic acid may cause oral diseases if insufficient metabolic utilization occurs. The metabolic utilization of a proper amount of nicotinic acid is required for the formation of the tissue enzymes that are concerned with the glycogen utilization and cellular respiration. The tongue may be reddened and void of papillae, and the dorsal and lateral margins appear ulcerated. All of the tissues of the oral cavity may be involved. Xerostomia (dry mouth) may result from involvement of the salivary glands as a result of a deficiency. Often a reddening of the oral mucosa and a burning sensation exist from a folic acid deficiency instead.

Vitamin C was observed many years ago. People who lacked fresh fruits and vegetables were particularily affected by weakness, fatigue, and hemorrhage of the skin. The cellular involvement resulted from a lack of production of connective tissue intercellular substance. Vitamin C also affects bone formation, blood development, and tissue susceptibility to disease and infection. Oral tissues are exceptionally susceptible to avitaminosis C. The gingival tissues take on a typical gingivitis picture. The gingivae are enlarged, hemorrhagic, and bluish red in color. The periodontal membrane is affected, and the teeth may become loose. Secondary infection often occurs and complicates the disorder.

Vitamin D is concerned primarily with calcium and phosphorus absorption from the intestinal tract and thus can cause a deficiency of minerals. Vitamin D is more important in tooth formation than in the maintenance of general dental health. The entire body reacts to the lack of calcium and phosphorus, and this adverse reaction is the most important result of a vitamin D deficiency.

Vitamin K produces disturbances in dental health when deficient. The oral tissues may be highly susceptible to trauma and spontaneous hemorrhage may occur. Vitamin K also has a connection with the lactobacilli count. Fosdick found that when vitamin K was present in the oral cavity, lactobacilli multiplied less rapidly.[5]

Other conditions exist because of a deficiency of minerals. Angular cheilosis is not always caused by niacin deficiency or an insufficient vertical dimension of occlusion. Angular cheilosis may be caused by iron deficiency. Thus, the causative

agent of some disorders is complicated and complex enough to require skill and time for proper diagnosis. Minerals are needed and utilized in many metabolic reactions, and proper amounts of each element are essential for good nutrition.

RESPONSE TO ORAL SURGERY

The response to surgical operation is similar to responses to diseases of the gums and supporting tissues of the teeth. If improper nutrition exists, the body does not allow proper healing. Proper food products and their efficient utilization are required for proper healing. Protein is needed to help build new tissue. Calcium is needed to help form new bone. Vitamin K must be utilized for proper formation of blood clots. Vitamin C is utilized in wound healing. Vitamin C and calcium are both needed, but older people have reduced stomach acid production. Both of these nutrients require acidity to be absorbed properly. Thus, supplemental vitamins C and K are given with calcium both before and for a period after surgical procedures.

RESPONSE TO PROSTHESIS

One of the common nutritional problems concerns older patients with prosthetic restorations. Many people without teeth are forced to a high carbohydrate diet. When dentures are made, these patients are unable to stand the stresses placed upon the tissues. This situation results in a cycle where nothing is accomplished. If the tissues are to withstand the stresses and strains of dentures, proper nutrition is essential. The patient should be built up physically by proper nutrition before denture construction begins, so that he can tolerate denture service.

Patients must be instructed in the correct use of dentures so that their physical and dental health will be maintained. Food may be cut into smaller pieces so that less work is required to maintain normal nutrition. The patient must chew each morsel of food longer to masticate it efficiently for the stomach.

SUMMARY

Some of the dental problems that arise as a result of nutritional deficiencies have been discussed. Good physical health resulting from proper nutrition will bring about good dental health. However, good dental health involves more than nutrition.

A proper diet for the average person may not result in proper nutrition if the body is not functioning properly. If the body is working properly, a sound diet is necessary to keep physically and dentally fit. For the geriatric patient, it is possible to be sure that proper nutrition exists only if a complete physical examination is given periodically and tests are made to indicate the correct diet.

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SURGICAL PROSTHESIS

POSTSURGICAL PALATAL OBTURATOR

A Case Report

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A 58-YEAR OLD WHITE MALE patient had symptoms in the right maxillary sinus for at least a year. The first symptom was itching on the face, followed by eventual pain in the teeth. Swelling of the right cheek had been present for 2 to 3 months (Fig. 1), with a somewhat purulent discharge at times from the nose. The patient was otherwise in excellent health. He smoked a pack and a half of cigarettes daily.

Because of the pain in the teeth, the patient went to a dentist, who removed the upper right cuspid, bicuspids, and molars. No roentgenograms were made. The pain increased after the extractions. The patient went to a physician, who referred him to an oncologist. A biopsy was made, and the lesion was diagnosed as a tumor of the antrum.

Preoperative records including a facial moulage, study casts, and photographs were made. The specimen was removed en bloc, leaving an adequate margin. The ethmoid and sphenoid sinuses were curetted, and a skin graft from the abdominal wall was used to cover the bony defect.

TEMPORARY OBTURATOR

The original stone cast was duplicated and trimmed to simulate the approximate condition of the patient's mouth after surgical operation. On the fifth postoperative day, a cold-curing, clear acrylic resin tray was made on this cast and corrected with modeling compound to fit the defect (Fig. 2). An impression was made in an irreversible hydrocolloid material.

A temporary obturator was constructed (Fig. 3) and placed in the mouth on the seventh postoperative day. The obturator consisted of three half clasps made of narrow gold wire. The clasps fitted around the premolars and molar which had previously been reduced interproximally. A palatal portion fitted the defect. The obturator gave satisfactory service for several weeks, during which time adjustments were necessary. One premolar clasp was removed to reduce pressure.

Read before the American Academy of Maxillofacial Prosthetics, New York, N. Y.

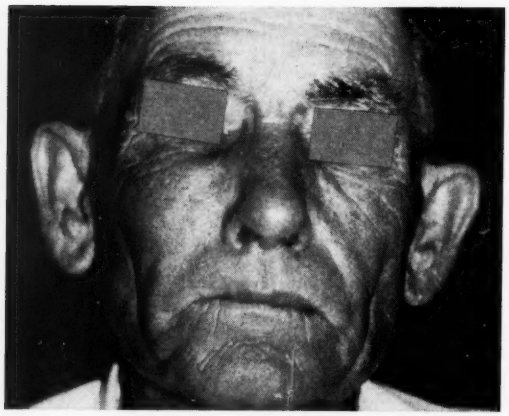

Fig. 1.—A swelling is present in the region of the right zygoma.

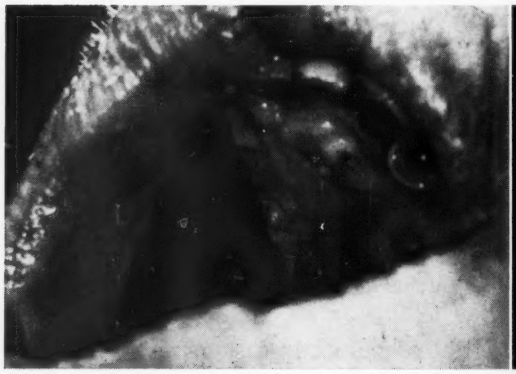

Fig. 2.

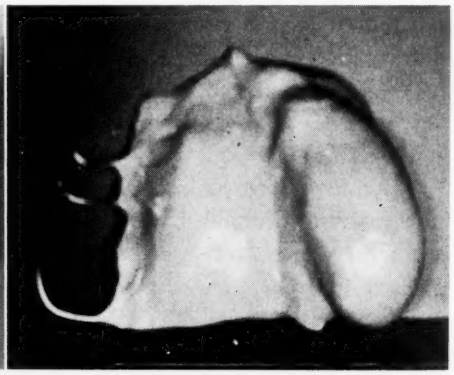

Fig. 3.

Fig. 2.—The defect 7 days after surgical operation.
Fig. 3.—The temporary obturator includes a palatal portion that fits the defect.

Fig. 4.—A cast made 1 month after surgical procedures.

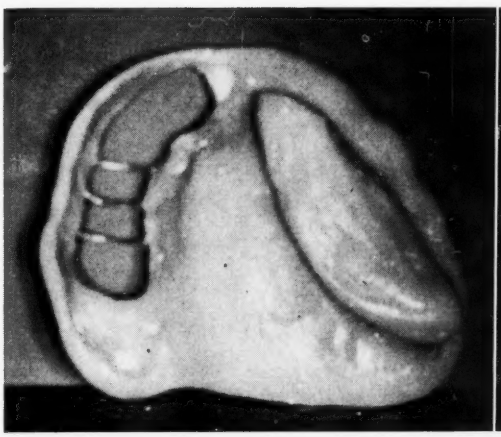

Fig. 5.

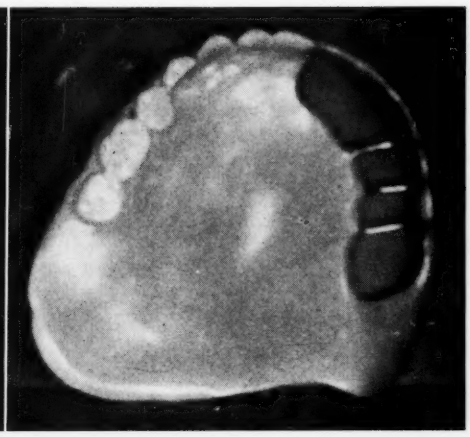

Fig. 6.

Fig. 5.—The natural teeth extend through the space in the denture base. The wires fit in the interproximal spaces between the natural teeth.
Fig. 6.—The artificial teeth are supplied by the restoration.

Fig. 7.—The restoration is in place in the mouth.

PERMANENT OBTURATOR

A more stable and permanent restoration was constructed after 1 month, when sufficient healing had taken place. Impressions were made with a nonpressure technique. The new cast showed that a tremendous amount of shrinkage of the tissue had occurred (Fig. 4). Therefore, we decided to make a restoration that would have less mobility than the first denture.

The new restoration was extended to cover the same tissue as would a complete denture, except where the remaining teeth projected through the denture base (Figs. 5 and 6). The denture base around the buccal mucosa was connected to the palatal denture base by gold clasp wires that ran interproximally between the natural teeth.

The new restoration enabled the patient to speak clearly and eat and drink with a minimum of discomfort (Fig. 7). Except for minor adjustments, the restoration has been satisfactory.

SUMMARY

This case report illustrates a simple technique for early prosthetic reconstruction of a surgically produced palatal defect. The restoration is easily constructed and requires few postinsertion adjustments. A temporary restoration that requires little presurgical preparation is often necessary because of time and economic factors.

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TEMPOROMANDIBULAR JOINT DYSFUNCTION

DYSFUNCTIONAL TEMPOROMANDIBULAR JOINT AND MUSCLE PAIN

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MANY PATIENTS with temporomandibular joint and muscle pain have had to learn to live with the symptoms although they have been exposed to a variety of treatments. In some instances the symptoms have been aggravated by the treatment,[1] while other patients have recovered without treatment.[2,3]

The purpose of this study was to investigate, clinically and electromyographically, the relationship between occlusal disharmony and pain in the temporomandibular joint and adjacent structures and to search for rational therapy for these disorders.

PATIENT SELECTION

Thirty-two patients (20 men and 12 women) with pain in the temporomandibular joints or jaw muscles were selected. Their ages varied from 19 to 60 years (mean age 32 years). All of the patients had a fairly complete dentition, although several had fixed partial dentures and 1 had a removable mandibular partial denture with free end denture bases. Twenty-seven patients had pain in the temporomandibular joints and various degrees of muscle pain, while the remaining 5 patients had only muscle pain. The symptoms varied from constant severe pain and marked trismus to occasional discomfort and pain with insignificant impairment of function. The duration of the symptoms varied from 1 month to 10 years.

Ten of the patients had been treated unsuccessfully by occlusal adjustment or reconstructive dental procedures. One patient had been treated by several dentists for 10 years.

METHODS

A detailed clinical and electromyographic analysis of occlusion was performed on all subjects before and after occlusal adjustment. The electromyographic study

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was limited to the masseter and the posterior, middle, and anterior parts of the temporal muscles on both sides.[4-9] The recordings were made on an eight channel electroencephalograph* modified for electromyography. A single channel and an eight channel oscilloscope were integrated with the inkwriter of the electromyograph. Surface electrodes were used exclusively, with the ear lobes as reference points (Fig. 1).[5,6] The patients were comfortably seated upright, with no head support, in a dental chair within a Faraday cage.[10] They were instructed to look levelly at the opposite wall. The surroundings were kept as quiet as possible.

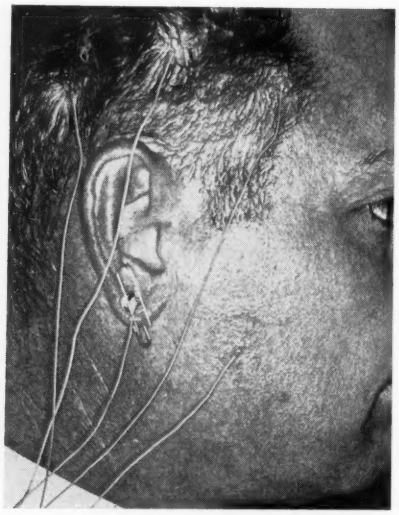


Fig. 1.—The surface electrodes were attached with collodion. Similar arrangements of electrodes on the other side of the head allowed for simultaneous bilateral recording.

The initial electromyographic examination was performed after a short interview to prevent conditioning of the patient through the location of occlusal interferences. Records were made of rest position (clinical and electromyographic), tap from rest position to light occlusal contact, closure to maximal contact (centric occlusion)[11] and release, swallowing of various amounts of water with the cup away from the mouth and "empty" swallow with and without command, location of centric relation[11] by mild posterior pressure on the mandible, tapping the teeth together with the jaw in centric relation, slide from centric relation to centric occlusion, lateral and protrusive excursions with the teeth in contact, lateral and protrusive excursions without occlusal contact, and mastication of chewing gum on the right and left sides and on the anterior teeth. Each procedure was repeated several times. The rest position was re-examined at the end of the recording session, which lasted 45 to 60 minutes. The oscilloscopes were impractical because of masking of electric waves on the screen during occlusal contacts, so these were used for only a few patients.

*Grass Model IV A.

A medical and dental history was obtained[12] after the initial recording. Main emphasis was placed on (1) symptoms related to the chief complaint, (2) mental and physical stress, (3) past dental treatment, (4) clinical examination of the temporomandibular joints, (5) examination of the jaws and neck muscles, and (6) occlusal analysis including examination of the habitual masticatory pattern.

An attempt was made to locate occlusal interferences in centric relation and in lateral and protrusive excursions. However, because of the "splinting action" of the muscles associated with joint pain, it was difficult and sometimes impossible to locate the initial occlusal contact in centric relation or to determine the extent and direction of the slide from centric relation to centric occlusion. A gentle and reassuring approach to the patient greatly facilitated this part of the examination.

Temporomandibular joint roentgenograms were made only when indicated for differential diagnosis or in instances of marked clinical derangement of the joints.

OCCLUSAL CORRECTION

Gross occlusal interferences in centric relation and on the balancing side were removed first. After 2 to 4 days, the main symptoms of pain had usually subsided and a detailed occlusal adjustment was made. A third adjustment was made a week later and a fourth a month later for control. Unavoidable resettling of the teeth after the first two or three adjustments occasionally resulted in new interferences that had to be eliminated before a stable harmonious occlusion was established.

The clinical criteria for completion of the occlusal adjustment were (1) absence of slide from centric relation, (2) balancing side contacts distinctly lighter than working side contacts in retrusive lateral movements, and (3) smooth, unrestricted gliding movements for the working side and protrusive excursions. Zoxazolamine* was used to obtain muscle relaxation for 4 patients. No other drugs or treatment splints were utilized.

A new electromyographic recording was made when the occlusion appeared to be well adjusted clinically. In several instances, minor residual occlusal interferences were detected electromyographically. Additional occlusal adjustment was performed and the electromyographic recording repeated until there was evidence of an ideal occlusion. This necessitated two to five electromyographic recordings for each patient.

The patients were kept under surveillance after the adjustment and re-examined for possible recurrence of occlusal interferences or discomfort during the 3 years of the study.

Psychotherapy was not attempted. However, the patients were told that a correlation probably existed between their symptoms and their mental stress or tension.

CLINICAL FINDINGS

Variations in psychic tension appeared to be closely related to the temporomandibular joint and muscle symptoms. Tension associated with examination periods, domestic or marital problems, and premenstrual tension were some of the

*Flexin.

situations that would bring on or aggravate the symptoms. Three patients related the onset of their symptoms to the placement of dental restorations. All patients had clinical manifestations of bruxism.

The functional analysis revealed occlusal disharmony of varying severity in all patients. The most consistent observation was a discrepancy of from 0.5 to 4 mm. between centric relation and centric occlusion. This slide to centric occlusion was usually a combination of a protrusive and a lateral movement and often changed direction during the slide. However, a few patients had a straight protrusive slide and a few others had an almost straight lateral slide. The slide to centric occlusion was usually away from the painful joint. In a few instances when in centric relation the teeth on one side contacted before those on the other side, the pain occurred on the noncontacting side.

More than one-half of the patients had heavy contact on the balancing side in at least one of the lateral excursions, and some patients had such severe balancing interferences that working side function was impossible. Pain associated with balancing interferences most commonly occurred on the side of the interference. The steepness of the cuspal inclines on the working side and the amount of vertical overlap of the anterior teeth varied from flat occlusal surfaces and anterior end to end occlusion to steep cusps and extreme vertical overlap.

Adjustment of the working side and protrusive excursions was delayed until the centric relation and the balancing interferences had been removed. A working side interference which was more than 2 mm. from centric relation on a steep lingual incline of a cuspid maintained the temporomandibular joint symptoms of 1 patient. The symptoms disappeared when the cuspid was adjusted so the adjacent teeth also engaged in working contact relationships.

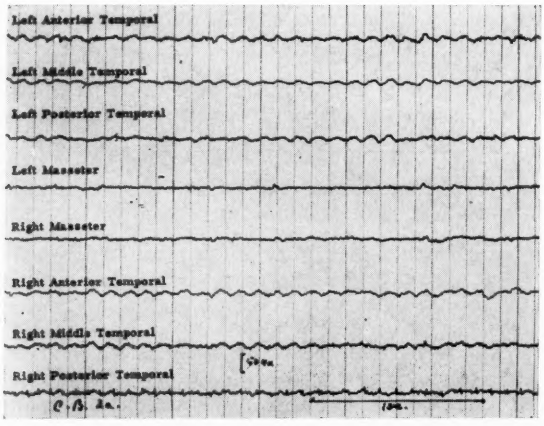
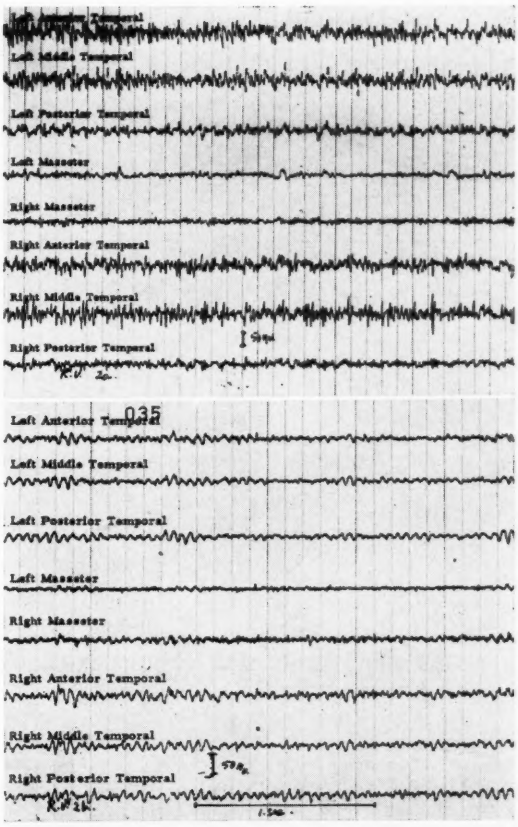


Fig. 2.—An electromyogram shows normal postural activity in rest position. The slightly wavy pattern of the recordings is due to brain waves rather than to muscle activity. By relaxing the patient, this normal record was obtained in spite of the following symptoms, which had been present for 4 months: (1) locking of the jaws for up to 2 hours after awakening in the morning, (2) uncontrollable resistance to opening of mandible for the rest of the day, with only one-half of normal opening, (3) pain and cracking in the left temporomandibular joint, (4) pain in the jaw muscles both at rest and during mastication, and (5) grave occlusal disharmony in centric relation and in lateral excursions related to previous "occlusal rehabilitation."

Several patients had ledges worn on the incisal edges of the anterior teeth from bruxism. When the teeth were moved over these ledges in combined working and protrusive excursions, in some instances pain was elicited in the more distant temporomandibular joint. Such movements were invariably accompanied by a click in the joint. The click usually disappeared at the moment the ledges were removed by occlusal adjustment. Other types of clicks gradually subsided within 3 to 4 months after adjustment, while in a few instances an occasional painless click with wide opening persisted over the time of observation.

Only 3 patients had a bilateral harmonious pattern of mastication at the initial examination. The other patients had a unilateral or protrusive preferred occlusal path for chewing.

A.



B.

Fig. 3.—*A*, An electromyogram from an unsuccessful attempt to obtain muscle relaxation and rest position. The patient had marked discomfort and some pain in the jaw muscles but no pain in the temporomandibular joint, severe bruxism, a slide from centric relation of 1 mm. forward and to the left, and an interference on the left first maxillary bicuspid in left lateral excursion. The patient chewed on the right side only. *B*, A record from the same patient as in *A*. This recording of rest position was made 1 week after occlusal adjustment. A fairly harmonious and minimal activity in the muscles is seen in spite of a more sensitive gain setting.

Most patients with unilateral pain in the temporomandibular joint preferred to chew on the painful side. A few patients with severe balancing interference chewed on the side opposite to the painful joint, and their pain was chiefly associated with mastication. Invariably, these patients had severe obstructions to lateral working function on the side with the painful joint, thus forcing them to chew on the opposite side and exposing them to disturbing balancing interferences.

All patients were completely free of pain and discomfort in the temporomandibular joints and adjacent structures at the time the study was terminated. As far

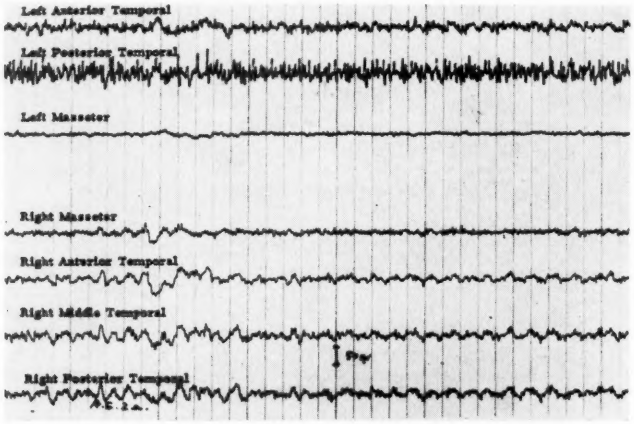


Fig. 4.—An electromyogram shows a failure to achieve relaxation of the left posterior part of the temporal muscle in rest position. The patient had severe continuous pain in the left temporomandibular joint and had a marked psychic stress and severe bruxism. There was a 4 mm. forward slide from centric relation. A severe balancing interference was present from a tipped lower molar on the left side which made it impossible to chew on the right side. The patient chewed on the left side, but a balancing interference was also present for this excursion. In spite of continuing psychic stress, this patient has been completely free of symptoms since the occlusion was adjusted.

as it could be ascertained, all patients had ended bruxism in lateral excursions. Two of the patients stated that they occasionally clenched their teeth in centric occlusion under tension but had no discomfort associated with the clenching.

ELECTROMYOGRAPHIC FINDINGS

Rest Position.—No attempt was made to quantitate the electromyographic response in an absolute sense. The concern was only with relative changes in muscle activity of a clearly distinctive nature.

Balanced, minimal muscle activity corresponding to an "electromyographic rest position" was recorded in 20 patients after various relaxing procedures (Fig. 2). A slight opening from the clinically determined rest position often enhanced the muscle relaxation, and the mandible could be opened about ½ inch further with no change in the rate of contraction. This "resting range" has also been described

for the suprahyoid muscles by Garnick.[13] Elimination of noise and eye strain, soothing conversation augmented by suggestive induction in relaxation, and holding the teeth apart for some time to eliminate the muscle memory of occlusal interferences were the methods used to minimize muscle activity. Only 8 of the 20 patients had well-balanced, minimal muscle activity in the rest position prior to these relaxing procedures.

Minimal, uniform activity in the muscles prior to the occlusal adjustment could not be obtained in 12 of the 32 patients. Therefore, these patients did not have an

Fig. 5.

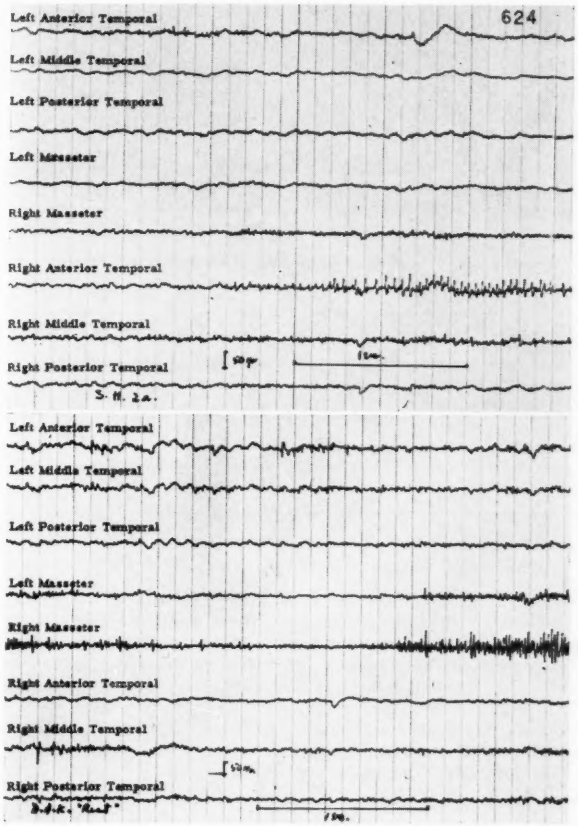
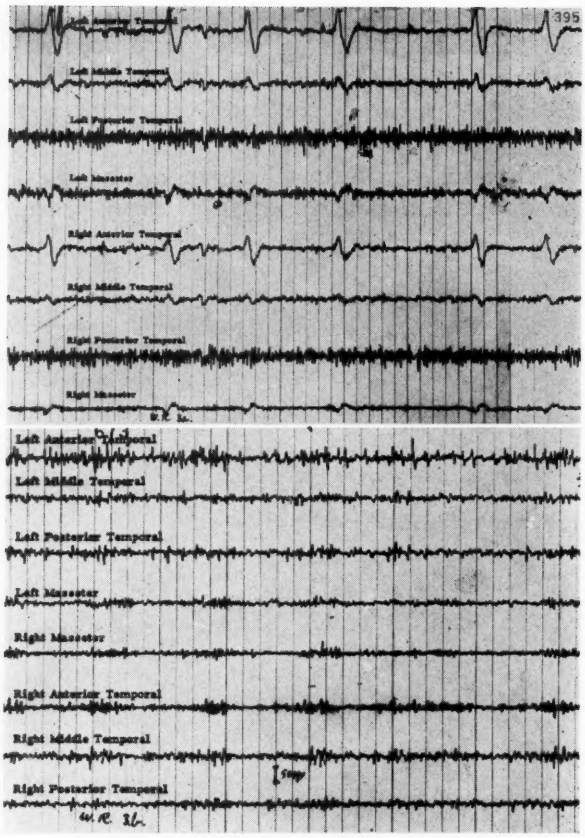


Fig. 6.

Fig. 5.—A twitch started in the right anterior part of the temporal muscle (middle of record) while the patient was holding the jaw in rest position. The patient had a severe occlusal disharmony and pain in the left temporomandibular joint and jaw muscles. There was a marked slide in centric relation that tipped the jaw 2.5 mm. forward and to the right. The muscle twitch did not appear after the occlusal adjustment.

Fig. 6.—Note the temporary relaxation of all muscles in the middle part of the record as the patient moved the mandible into a protrusive "resting position." However, the pain in the right temporomandibular joint and the spastic contraction of the masseter muscles reappeared within a second (worst in the right masseter muscle). The spastic contractions and the associated pain became more severe until the patient moved the jaw into a new position, with temporary relief again. This situation followed an almost completed occlusal adjustment. The only residual interference was on the lingual surface of the left maxillary cuspid in left lateral excursion.

A.



B.

Fig. 7.—*A*, A record of attempts to tap the teeth together from the clinical rest position. Because of severe pain in the left and mild pain in the right temporomandibular joint, it was impossible to obtain a relaxed, harmonious tonic contraction or electromyographic rest position in this patient. Note the sustained tension in the posterior parts of the temporal muscles and to a lesser degree in the left masseter muscle. The large amplitudes on both anterior temporal recordings are movement artifacts from the patient blinking her eyes. *B*, The same patient as in *A*, after occlusal adjustment, performing the same tapping movements. Note the harmonious contractions and relaxation of all of the recorded muscles.

electromyographic resting range (Fig. 3). Commonly, the increased or disturbed activity was recorded from the posterior part of one of the temporal muscles, usually on the side of the painful joint (Fig. 4). This lack of a resting range was associated with severe pain in the temporomandibular joint or a high degree of psychic tension.

Occasionally, the muscle activity increased for no apparent reason during relaxing procedures with the teeth apart. This muscle twitch noted electromyographically (Fig. 5) could also be observed clinically. One patient had the least disturbed muscle pattern when she held the teeth lightly together. Another patient with severe pain in the right temporomandibular joint got relief from pain when

he held the jaw in a protrusive position. This position gave a short transient rest recording electromyographically which, however, was followed by spastic contractions in the masseter muscle (Fig. 6). It was easier to induce muscle relaxation when the pain was in the muscles rather than in the joint structures.

Well-balanced, minimal muscle activity during rest position was recorded for all of the patients after complete occlusal adjustment.

Occlusal Contacts.—Patients who exhibited sustained muscle strain during the recording of rest position also were unable to relax these muscles between occlusal contacts when they tried to tap the teeth lightly together (Fig. 7). Tapping the teeth together from rest position was an unreliable method for detection and evaluation of occlusal disharmony since some patients, in spite of occlusal disturbances, gradually would tap the teeth into a fairly harmonious occlusal contact relationship. The initial one or two taps after the patient had been sitting with the teeth apart for some time were most likely to reveal the occlusal disharmony.

Closing the teeth lightly together in centric occlusion often revealed an unharmonious contraction pattern associated with occlusal imbalance, especially if some of the teeth were contacting on one side first. The muscle activity was greater on the side of the initial contact than on the other side. If the patient closed the teeth firmly together, however, a large number of fibers participated in all of the muscles recorded, and the uneven occlusal contact relationship was masked by this general, heavy activity.

Most of the patients had an acquired centric occlusion with fairly well-balanced muscle activity. In a few patients, muscle spasms and pain developed when the teeth were held together in centric occlusion for a few seconds (Fig. 8).

Swallowing.— Swallowing was the only step in which all of the patients exhibited a disturbed electromyographic contact pattern prior to the occlusal adjustment. Five patients consistently had the teeth apart when they swallowed, and several others exhibited occlusal contact only occasionally in an "empty" swallow

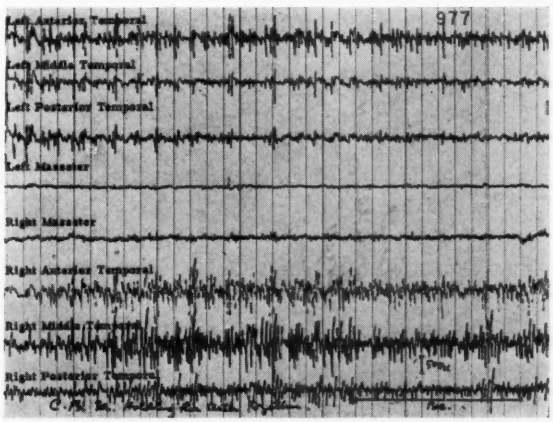


Fig. 8.—The same patient as in Fig. 2, before occlusal adjustment, showing biting with a light even pressure in centric occlusion. Spastic, uneven, and uncoordinated contractions are seen in the temporal muscles.

Fig. 9.

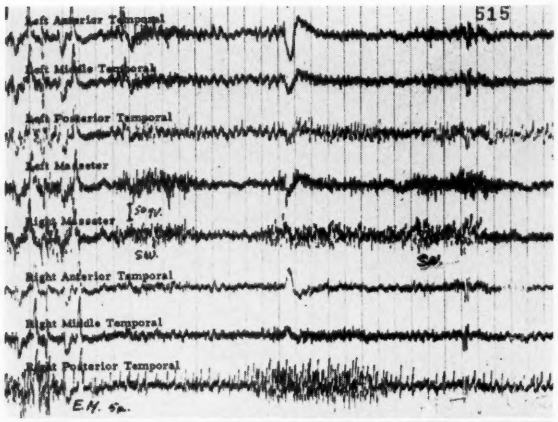


Fig. 10.

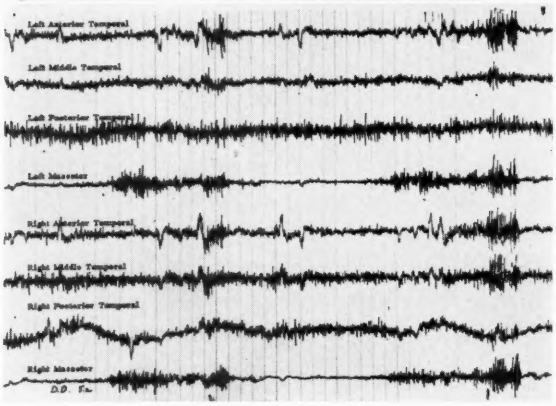


Fig. 9.—An electromyogram made during swallowing water with the cup away from the mouth. The patient had severe pain in the right temporomandibular joint and muscle discomfort on both sides. There was a 1.5 mm. forward slide from centric relation and severe interference and restricted lateral excursions. Note the sustained tension, lack of coordination, and spasms associated with pain in the posterior part of the right temporal muscle (bottom, middle of record).

Fig. 10.—An electromyogram made during swallowing water with the cup away from the mouth. The patient had pain in the left temporomandibular joint and severe bruxism, with a tiredness and dull ache in several jaw muscles being most severe in the temporal regions on both sides. There was a 1.5 mm. slide from centric relation forward and to the right side. Note the sustained heavy activity in the left posterior and the right middle and posterior parts of the temporal muscles.

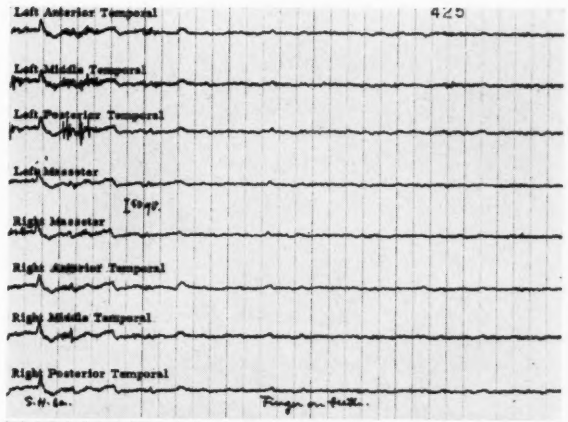
or when swallowing large mouthfuls of water. These patients held the tongue in various positions between the teeth when they swallowed. Spastic muscle contractions appeared completely out of harmony with the rest of the recorded muscles in some individuals (Fig. 9), while in others sustained, heavy muscle contraction indicated an abnormal activity or tension in the muscles associated with swallowing (Fig. 10).

All of the patients developed a swallow with the teeth together and a harmonious correlation of contraction and relaxation during and following the act of

swallowing after completion of the occlusal adjustment. This muscle harmony in swallowing was obtained consistently only when the jaws could be brought together in centric relation without any slide, slip, or trip of the mandible.

Centric Relation.—An attempt was always made to locate centric relation by applying mild distal pressure on the lower anterior teeth, combined with relaxing procedures. In most instances, less muscle activity was recorded when the patient's jaw was supported by the dentist than in regular recording of rest position (Fig. 11). However, in patients with severe temporomandibular joint pain, it was not possible to achieve either clinical or electromyographic evidence of relaxation by

Fig. 11.



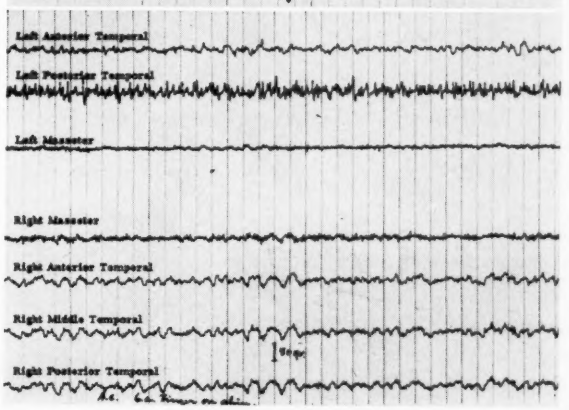


Fig. 12.

Fig. 11.—The same patient as in Fig. 5. The recording of rest position extends on the extreme left of the record to the end of the words "left masseter." During the remainder of the recording, the dentist was pushing the patient's jaw posteriorly into centric relation with the thumb on the lower anterior teeth. Note that more complete relaxation of the muscles was obtained with posterior pressure on the teeth than in rest position.

Fig. 12.—The same patient as in Fig. 4. The record shows an attempt to bring the jaw into centric relation by mild posterior pressure on the patient's chin and relaxing procedure. Neither clinical nor electromyographic muscle relaxation could be obtained prior to occlusal adjustment in this patient because of the severe pain in the left temporomandibular joint. A sustained muscle contraction is seen in the left posterior temporal region.

this method (Fig. 12). Harmonious relaxation was later achieved in subsequent appointments when the pain had been eliminated by partially completed adjustments.

Bilateral tension was recorded over the posterior part of the temporal muscle when the patients attempted to hold the jaw in centric relation. Occlusal interferences were recorded in this position (Fig. 13), but the muscle strain associated with the posterior positioning of the mandible was difficult to differentiate from the effect of pain when the patient was holding the jaw in centric relation. Some noticeable activity in the posterior part of the temporal muscles was also required after the adjustment to hold the mandible in centric relation. However, the contraction pattern was equal bilaterally. The patients' attempts to reproduce a slide from centric relation to centric occlusion did not yield useful information.

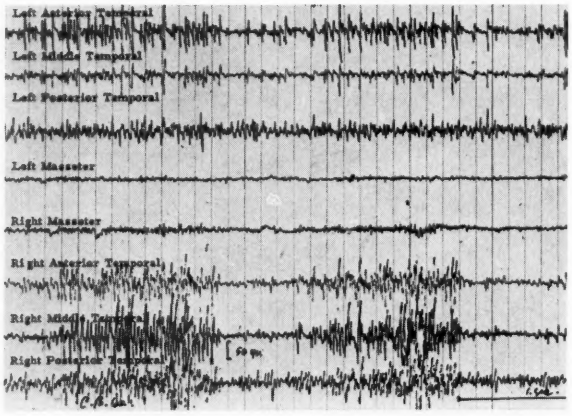


Fig. 13.—The same patient as in Figs. 2 and 8, biting into contact and opening slightly in centric relation prior to the occlusal adjustment. Irregular spastic contractions in the various parts of the temporal muscles are associated with pain and discomfort in these muscles.

Eccentric Positions.—Splinting action and paroxysmal spastic contractions of the muscles were observed in several patients on lateral and protrusive excursions with or without occlusal contacts (Figs. 14 and 15). Occlusal interference on the balancing side had the most disturbing effect upon the contraction pattern of the muscles. In several instances, the patients could not make lateral excursions even with the teeth apart, because of the splinting action of the muscles caused by pain in the temporomandibular joints or muscles. The lateral and protrusive movements were often jerky. Snapping noises in the temporomandibular joints and associated jerky movements of the jaws resulted in characteristic movement artifacts in the electromyographic recordings (Fig. 16). Spastic muscle contractions and temporomandibular clicks or snaps also occurred during movements from the masticatory wear pattern into the bruxism pattern (or moving the other way) when ledges were present between these two facet patterns. Only in 1 patient with extremely tense muscles and temporomandibular joint pain were the most severe muscle spasms associated with a heavy working side contact on a steep lingual incline of a maxillary cuspid.

Harmonious bilateral and protrusive movement patterns with or without occlusal contact were recorded in all patients after occlusal adjustments and elimination of pain (Fig. 17).

Almost all of the patients had developed a habitual unilateral or protrusive preference pattern of mastication that showed electromyographically excellent muscle coordination. Disturbances in the contraction pattern were observed when the patients tried to chew away from this preference pattern. Three patients had an ideal bilateral masticatory pattern both from a clinical and an electromyographic standpoint and had no discomfort or pain associated with mastication. The bruxism and temporomandibular joint and muscle pain were related to a slide from centric relation that did not disturb the masticatory pattern. Electromyographic evidence of a disturbing slide from centric relation during mastication was obtained from only 1 patient, although all patients had various degrees of such a slide.

Heavy balancing interferences were readily observed in the electromyographic records of mastication (Fig. 18). Records of a balanced and well-synchronized contraction pattern in bilateral mastication were obtained from all of the patients after the completed occlusal adjustment (Fig. 19).

DISCUSSION OF FINDINGS

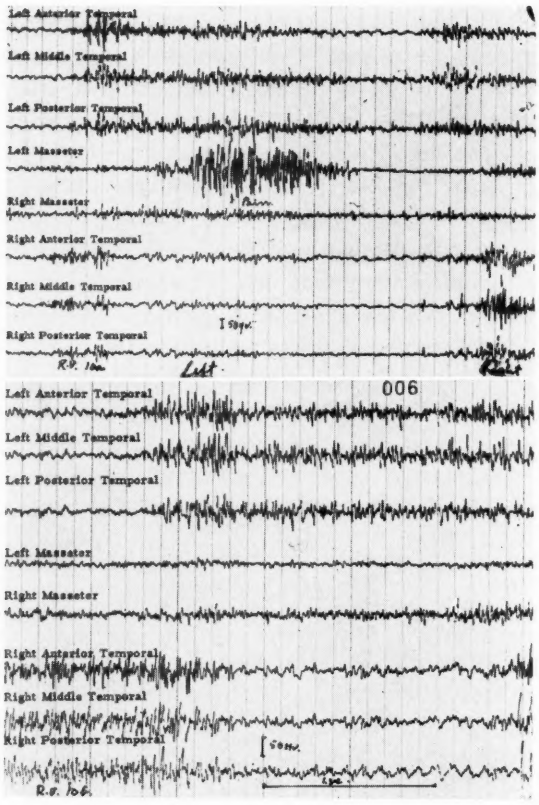
Rest Position.—Jarabak[14] and Perry[15,16] consistently found an abnormal electromyographic contraction pattern in rest position in patients with temporomandibular joint disturbances. However, Kydd[17] found a normal pattern in all but 1 of 31 patients with temporomandibular joint disturbances. This study indicated that patients with such disturbances may or may not have a normal muscle activity in rest position. Postural activity of the muscles is always present in rest position.[18,19] However, harmonious muscle action in rest position is not acceptable as electromyographic evidence of occlusal harmony and temporomandibular joint comfort,[14-16] since muscle harmony and relaxation were observed also in patients with occlusal interferences and muscle discomfort.

All of the patients who had a disturbed muscle pattern in rest position developed a normal harmonious pattern after adjustment. To what extent the improvement was due to the removal of the occlusal interference or to the elimination of pain cannot be determined from this study. The important factor in muscle contraction patterns of psychic tension was not intentionally altered during the study. It appeared that pain signals influenced or conditioned the occlusal and postural reflexes more than occlusal interferences.

Normal muscle activity and complete relief of symptoms were attained in all patients without any change in the vertical dimension of occlusion. This substantiates the contention of Cobin[20] and Miller[21] that temporomandibular joint disturbances usually are not manifestations of "distal displacement" of the condyle and "mandibular overclosure."[22] The relief of muscle spasm obtained by opening the vertical dimension with splints apparently is due to elimination of occlusal interferences by the splint rather than to the altered interocclusal distance.

The increased muscle activity recorded in the region of the posterior parts of the temporal muscles with temporomandibular joint pain is interpreted as a splint-

A.



B.

Fig. 14.—*A*, The same patient as in Fig. 3. The electromyogram starts with the mandible in right lateral excursion (the teeth in contact), moving slowly over to left lateral excursion (middle of record). The mandible is moved back to right lateral excursion on the right side of the record. Spastic contractions in the left masseter muscle (middle of record) are associated with pain in the muscle during movement to the left. *B*, The same patient as in *A*, 1 week after completed occlusal adjustment, performing the same movements as in *A*. The increase in amplitudes at the left one-third of the record is associated with the change from right to left lateral excursion and is due to closing in centric occlusion as the patient passes through this position to the next excursion. This is normal. The same phenomenon can be observed on the right side of the record as the patient passes from left to right lateral excursion. Note the harmony in the contraction pattern and the relaxation on the side from which the patient moves. Compare this record with the irregularities shown in *A*.

ing action of the muscles in an attempt to hold the condyle away from the painful areas of traumatic injury within the joint. A different electrode arrangement must be used to establish the origin of this hyperactivity.

The rest position established by conventional clinical methods often did not correspond with the electromyographic range of miminal postural activity. This indicates that the word "physiologic" has been used too loosely in clinical definitions of rest position. Adequate data are not available to discuss the significance of the resting range of the muscles and the discrepancy between electromyographic and clinical rest position.

Occlusal Position and Centric Occlusion.—Most of the patients had electromyographic evidence of muscular imbalance related to occlusal interferences when they tapped the teeth into light occlusal contact from rest position or closed initially in centric occlusion. In a few instances, pain and recordable muscle spasms developed when the teeth were held lightly together. However, several patients with temporomandibular joint and muscle pain could tap the teeth together from rest position or close into centric occlusion without any clinical or electromyographic evidence of occlusal interference. These patients usually also had an ideal muscle pattern in rest position in spite of the occlusal interferences in the various other occlusal relationships. Therefore, an ideal muscle pattern in rest position, occlusal position, and centric occlusion cannot be considered reliable evidence of complete occlusal harmony.[11]

Centric Relation.—The only tested mandibular function that consistently showed electromyographic evidence of muscle disharmony in all of the patients was swallowing. Furthermore, a harmonious contraction pattern in swallowing could be obtained only after an occlusal adjustment that eliminated the slide from centric relation to centric occlusion and established occlusal harmony with stability in centric relation (terminal hinge position). Centric relation is unquestionably a border position of the mandible,[23,24] and some electromyographically recordable effort is required by the muscles to bring the jaw into this position. That the mandible may be brought into centric relation in normal swallowing, as contended by Jankelson[25] and others,[26] was confirmed by the consistent harmonious contraction pattern and the swallow with the teeth together after complete occlusal adjustment in all of the patients. The muscular disturbances associated with swallowing in patients with a slide from centric relation was not in proportion to the magnitude of the slide. In emotionally tense individuals, muscle spasms in swallowing were

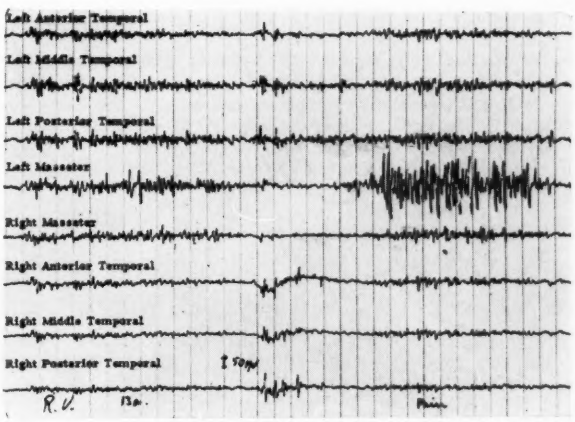
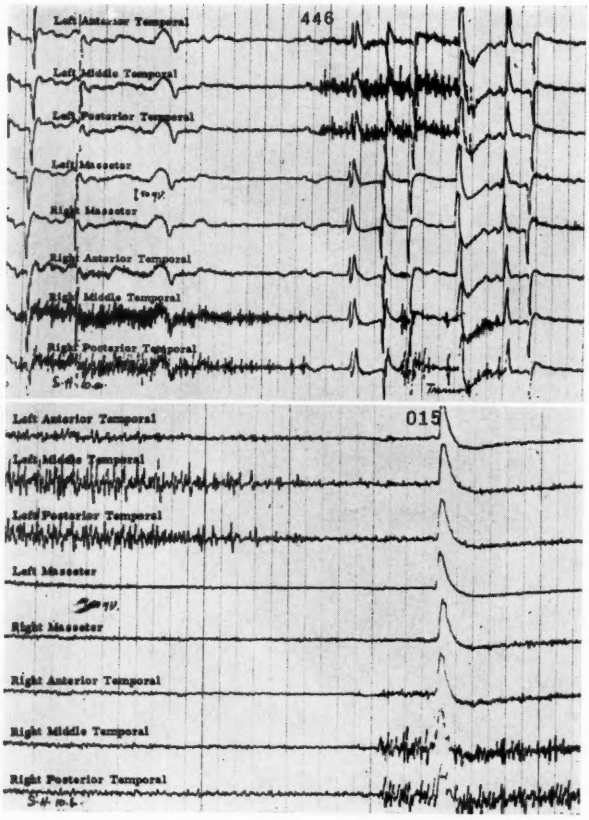


Fig. 15.—The same patient as in Figs. 3 and 14, before occlusal adjustment. The jaw was moved from the left lateral excursion to the rest position (middle of record) and then from rest position to left lateral excursion (right side of record). These movements were performed without occlusal contact of the teeth. Spastic contractions associated with pain in the left masseter muscle are similar to the recording in Fig. 14, for which the same movements were performed with the teeth in contact. The jaw movements were jerky clinically.

A.



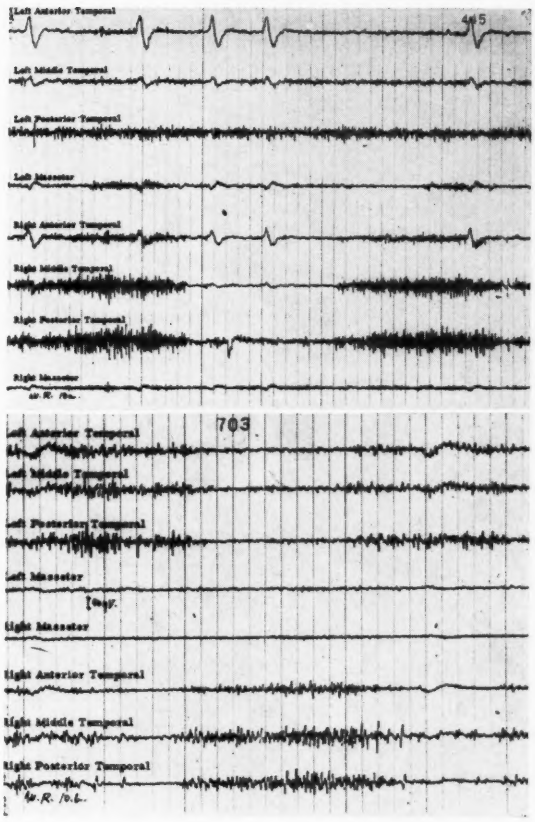
B.

Fig. 16.—*A,* The same patient as in Figs. 5 and 11. The movement is from right to left lateral excursion with the teeth in contact. The severe cracking and jerkiness in the temporomandibular joints resulted in the movement artifacts (extreme amplitudes). The patient had a clinically visible tremor in the right temporal muscle when he moved the jaw to the left. This can be seen at the lower right corner of the record. *B,* The same patient as in *A,* after occlusal adjustment. The movement is from left to right lateral excursion with the teeth in contact. One set of extreme amplitudes on the right two-thirds of the record is associated with an occasional cracking in the temporomandibular joint. The extreme cracking illustrated in *A* had almost subsided.

triggered by minute occlusal discrepancies as close as 0.1 mm. in front of centric relation, while some patients with 2 to 3 mm. slide had only slight disturbances.

That the slide from centric relation usually was to the side opposite that of the painful joint indicates that pressure on the anterior aspects of the involved joint is the source of the pain instead of a "distal displacement" of the condyle. The relief of the pain and the muscle spasms came with a repositioning of the condyle in a posterior rather than an anterior or downward direction in centric relation. Since a disturbance of the masticatory contraction pattern of the muscles in a slide from centric relation was recognized in only 2 of the 32 patients whose records showed such a slide in swallowing, the slide from centric relation was of far greater

A.



B.

Fig. 17.—*A*, The same patient as in Fig. 7. An attempt was made to perform lateral excursions from the right side to the left and to the right again with the teeth in contact. Continuous strain is seen in the posterior part of the left temporal muscle. *B*, The same patient as in *A*, following occlusal adjustment. Bilateral excursions were made from the left side to the right side to the left again with the teeth in contact. Compare with *A* and note the improved muscle harmony and the ease of bilateral movement.

significance for the swallowing contact of the teeth than for the masticatory contact. A general statement cannot be made from this limited material, but it appears that the masticatory contacts are commonly made in front of, lateral to, or at centric occlusion.

The greatest problem in the occlusal adjustment of patients with temporomandibular joint and muscle pain was to induce sufficient muscle relaxation to enable the dentist to locate centric relation. Any tension and resistance to manipulation of the jaw detected clinically were also apparent electromyographically. Zoxazolamine was of some value in reducing muscle tension in patients with mild muscle pain, but it was of no help in 1 patient with severe joint pain.

Muscle relaxation was obtained gradually in all patients by careful, painless procedures after initial elimination of gross interferences. In a few instances in

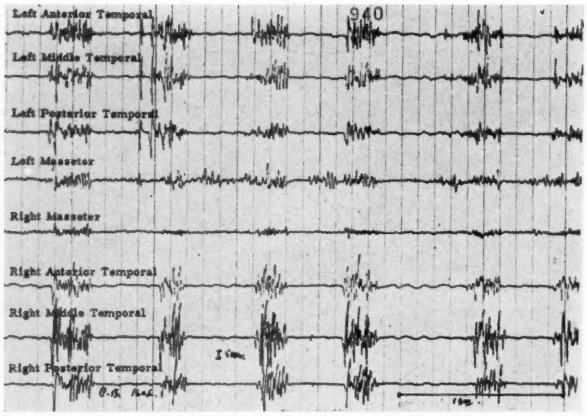


Fig. 18.—The same patient as in Figs. 2, 8, and 13, chewing gum on the left side. The amplitudes for the temporal muscles are larger on the balancing (right) side than on the working (left) side because of a balancing side occlusal interference.

other patients (not of this study), temporary occlusal splints have been used to achieve muscle relaxation prior to the adjustment. Such splints also have been widely recommended before the final recording of centric relation in restorative dentistry.[27,28] These splints are temporary crutches, however, and are not satisfactory treatment for patients with temporomandibular joint disorders.

If the functional analysis of the occlusion does not include an evaluation of centric relation and if the correction of centric relation interferences is done by tapping or biting into centric occlusion, the interferences in centric relation will be

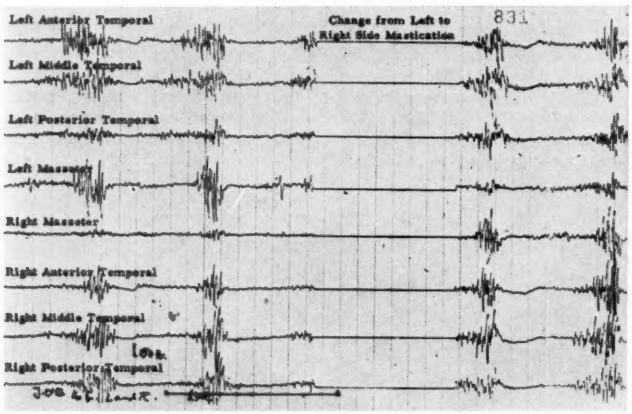


Fig. 19.—An electromyogram of normal bilateral mastication after occlusal adjustment. The patient changes mastication from the left to the right side at the middle of the electromyogram. Note the switch in the masseter muscle participation with the change in the side of mastication. The temporal muscles are active on both sides in mastication, but slightly less on the balancing side than on the working side. This indicates that the balancing side contacts are lighter than the working side contacts. This individual chews with practically no lateral movements, therefore the almost simultaneous contractions on both sides.

missed. Since interferences in centric relation maintain muscle spasms and joint pain in many instances, unless the occlusion is adjusted to centric relation, many patients will not experience relief of their symptoms from occlusal adjustment.

Lateral and Protrusive Excursions.—This investigation confirms reports that occlusal interferences on the balancing side have a disturbing and sometimes detrimental effect on the normal function of the masticatory system.[29] The increased muscle activity with heavy balancing contacts or interferences appeared to be an important factor in the etiologic background of temporomandibular joint injury and muscle spasms (Fig. 18).

It is of clinical significance that in routine lateral excursions with the teeth in contact, the neuromuscular mechanism frequently guided the jaw to avoid balancing interferences. These interferences could be detected only during guided lateral excursions that were outside of the patient's convenience pattern.

An opportunity to study the significance of the working and protrusive interference in the patient's pain complex was provided routinely by first adjusting only

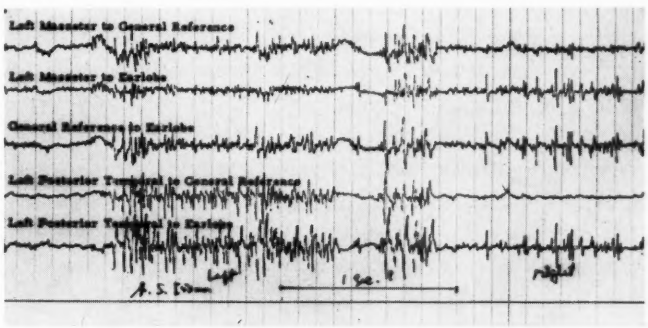


Fig. 20.—An electromyogram of bilateral movements with the teeth in contact. A difference in records is seen between the ear lobe reference and the "general" reference. The electromyogram starts with the mandible moving into an extreme left excursion. The jaw moves into centric occlusion in the middle of the record and then to right lateral excursion. Severe occlusal interferences are present. Note the difference between the ear lobe reference and the general reference in right lateral excursion. No marked differences are seen in the left excursion and centric occlusion.

the centric and balancing interferences. The steepness of the cuspal inclines, the incisal guidance, and the degree of vertical and horizontal overlap seemed to be of limited significance in the development of muscle and joint pain, provided smooth, unrestricted gliding movements free of balancing interferences were established. Only in 1 patient did interference on the working side alone trigger muscle spasms and temporomandibular joint pain. From a clinical and electromyographic standpoint, by far the most difficult dentitions to adjust were those on which cusps and incisal edges had been ground flat by bruxism or previously attempted occlusal adjustment.

Masticatory Pattern.—Although only 3 patients had an ideal bilateral masticatory pattern clinically and electromyographically prior to the adjustment, almost all of the patients had a satisfactory occlusal convenience pattern. The electromyo-

graphic manifestations of occlusal interferences often were minimal even when the patients chewed away from the convenience pattern, unless there were severe balancing interferences. However, some patients could chew only in a unilateral restricted pattern because of the pain. Therefore, examination of the masticatory habits of patients with temporomandibular joint disturbances was of limited value for the detection of occlusal interferences. The common tendency to chew on the side with the painful joint probably can be explained by the fact that less stress is exerted on the working side than on the balancing condyle during mastication. The few patients that chewed on the side opposite to the painful joint had either severe obstacles to function or loss of teeth on the side of the painful joint.

Placement of Electrodes.—Some question has been raised about the use of the ear lobes for electromyographic references.[30,31] The variations in arrangement of reference electrodes recommended by Hickey and associates[31] were tested against the ear lobe references used in this investigation. The magnitude of some of the electromyographic amplitudes varied with the reference, but, with the exception of recordings of contralateral movements, the slight variation in magnitude did not influence the timing and correlation of the contraction patterns. A definite difference in contraction pattern between the two sources of reference was observed when the jaw was moved away from the recorded side in a patient with malocclusion (Fig. 20). This observation might indicate that some of the hyperactivity that has been recorded in the posterior temporal region by ear lobe references has its origin in other muscles proximate to the ear lobe, for example, the sternocleidomastoid muscle. More study is needed to determine the definite origin of hyperactivity in the regions of the ear lobes. However, this observation does not alter the significance of the findings in this study, since whatever the source of the recorded hyperactivity, it was resolved to normal tonus activity after the occlusal adjustment.

SUMMARY

The relationship between occlusal disharmony and pain in the temporomandibular joint and adjacent muscles was tested clinically and electromyographically before and after occlusal adjustment on 32 patients. Various degrees of bruxism associated with psychic tension and occlusal interferences were observed in all of the patients. Clinically, all patients experienced relief of the pain and discomfort after complete occlusal adjustment. Electromyographically, a harmonious and well-synchronized contraction pattern of the temporal and masseter muscles was recorded after the adjustment.

Any type of occlusal interference was found to trigger muscle spasms and pain, but the most consistent and significant interference was a discrepancy between centric relation and centric occlusion. The muscle disharmony was displayed electromyographically mainly in swallowing. The second most significant occlusal disharmony was balancing side interference. The balancing side contact had to be lighter than the working side contacts to establish a harmonious masticatory pattern. The patients' symptoms subsided without altering the vertical dimension.

A close correlation was observed between the clinical and electromyographic recordings of occlusal interferences and muscle disharmony. However, electromyo-

graphic evidence of muscle balance in rest position could be obtained in more than one-half of the patients in spite of occlusal interference and temporomandibular joint pain.

Masticatory contacts were seldom observed posterior to centric occlusion. However, the occlusal contacts in swallowing apparently occurred between centric occlusion and centric relation. The occlusal stability in centric relation was found to be of extreme importance for muscle harmony during swallowing.

Rest position determined by conventional clinical methods did not always correspond to minimal, harmonious muscle activity electromyographically. A slight opening from the clinically determined rest position often facilitated the recording of an even, minimal contraction of the temporal and masseter muscles. The mandible could be opened from this position about ½ inch further (a resting range) without eliciting any increased muscle activity from these muscles.

CONCLUSIONS

1. Temporomandibular joint dysfunction and related muscle pain were eliminated by occlusal adjustment.
2. A discrepancy between centric relation and centric occlusion was the most common trigger for muscle spasms, bruxism, and dysfunctional temporomandibular joint disturbances.
3. A slide from centric relation is of much greater significance for the swallowing contacts of the teeth than for the masticatory contacts.
4. Electromyographic and clinical evidence of muscle balance in rest position is not an acceptable proof of ideal occlusal relations.
5. In no instance was distal displacement or mandibular overclosure the cause of the temporomandibular joint and muscle disturbances.

The electromyographic part of this study was made possible through advice, facilities, and assistance provided by Dr. Robert E. Moyers and Dr. Jesse L. Parks, University of Michigan, School of Dentistry. The author wishes to express his most sincere thanks for their interest and help.

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MISCELLANEOUS

RESEARCH AND THE FUTURE OF PROSTHODONTICS

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THE CURRENT STATUS OF DENTAL RESEARCH and particularly research relating to prosthodontics will be considered here. In doing so, I shall be discussing an activity which engages each of you in varying degrees. I use the term "research" in its broadest sense. Research is simply the habit of testing and correcting concepts by their consequences in experience. It is difficult to conceive of a successful prosthodontist who is not engaged in testing and correcting concepts by their consequences in experience. On the other hand, those who regard research as a very limited, profound, and even awesome activity engaged in by a few strange individuals will participate as learners who have discovered the values of being intelligently ignorant. After all, those in the profession who put knowledge remedially to account are as indispensable to the human enterprise as are researchers who bring new truths to light. Certainly no one will disagree with the concept that learning by doing creates its own obsolescence.

FINANCIAL SUPPORT FOR RESEARCH

Learning by doing, innovating, and developing were the principal avenues for progress in dentistry in this country until a decade ago when the Congress first appropriated funds specifically for dental research. In 1950, the Congress appropriated $200,000 to enable the National Institute of Dental Research to provide grant support for approximately twenty research projects in dental schools and in other research institutions. A total of $35,000 was appropriated for the training of research workers—enough to support eight to twelve fellows.

In retrospect, the pitifully small and woefully inadequate financial support of dental research in this country in 1950 reflected a strange conundrum. Although the American people were spending more than $1,500,000,000 a year for dental services—almost one-sixth of their total health dollar—less than 0.1 per cent of that amount was being expended in efforts to discover methods to prevent dental

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diseases or to improve control procedures. The comparable figure for the medical aspects of health is nearly 4 per cent.

Progress in gaining financial support of dental research during the decade of the fifties is reflected by a comparison of today's budget of the National Institute of Dental Research with that of 1950. Funds available for grants for dental research projects in dental schools and other research institutions throughout the country have increased from the 1950 figure mentioned earlier, $200,000, to more than $6,000,000. The number of projects supported has increased from twenty to more than 400. Support for research fellowships has increased twenty fold from $35,000 in 1950 to $760,000 in 1960.

In addition, almost $3,000,000 is currently available for grants to support a variety of training activities in dental schools. These include graduate research training programs and part-time student research fellowships for eight dental students in each of the dental schools and two students in each of the schools of public health. This year $800,000 was budgeted to support training units in dental schools to teach dental students to use chairside assistants effectively and efficiently.

During this same decade, the Congress has increased the appropriation for the direct operation of the National Institute of Dental Research from $276,000 in 1950 to slightly more than $3,250,000 in 1960.

All of us can find reason for being pleased with this support of dental research. The support, however, is still in its infancy, since a large part of it was made available in 1957 for the first time—just 3 years ago. It is still much too little and it is only roughly 0.5 per cent of the $2,000,000,000 now being expended by the public for dental health services. I am confident that the public is willing to spend more and that the financial support required to engage the ever-increasing number of dental research trainees in challenging research and teaching careers will be provided. Surely, a public which spent more than $17,000,000 for denture adhesives and denture cleansers in 1957 will be willing to spend substantially more for the research which could result in far more effective methods of prevention and control of dental diseases than those available now.

CURRENT RESEARCH PROJECTS

Even a summary review of projects and progress under this greatly expanded dental research program would be beyond the scope of this article. However, more than forty projects supported (roughly one-tenth of the total number of projects receiving support today) can be classified in the prosthodontic area. Included among these projects are such titles as "Stress Patterns in the Edentulous Human Mandible and Maxilla as Influenced by Complete Denture Forms," "Investigation of Magnetic Implant Dentures," "Study of the Morphologic Changes in the Jaws Following the Loss of Teeth," "The Effect of Tooth Forms on Denture Efficiency," "Velopharyngeal Action in Consonant Articulation," "Cinderadiographic Evaluation of Dental Speech Aids," "Evaluation of Resin Denture Bases," "Cinefluorography of Temporomandibular Articulation," "Electromyographic Studies on Mus-

cles of Mastication," "Measurement of Lateral Muscular Forces on the Teeth," "Oral Myometric Pressures," "Dental Function and Structure in Older Persons," "Alveolar Ridge Reconstruction With Alloplastic Implants," and "Relationship Between Chewing Efficiency and Dietary Habits in Older Persons."

Research in the areas suggested by the project titles just listed has done much to improve prosthetic service in all its aspects. Better materials have been produced, new techniques have been developed, and a better understanding of the oral mechanism, including neural and muscular anatomy, physiology, and function, has been fostered. With the general tendency toward longer life and the continuing increase in size of the older portion of our population, the need for research leading to improvements in prosthodontic services becomes more and more pressing.

The Report of the National Health Survey[1] shows that 22 million persons (13 per cent of the population) are edentulous. The percentage increases with age from about 1 per cent in the 15 to 24 years age group to 67 per cent in the 75 years and older age group. This survey revealed too that only 7 per cent of all edentulous persons 65 years of age and over had seen a dentist within the previous year. This finding suggests that we are failing to motivate edentulous persons to visit their dentist at regular intervals and that they are not active participants in a program of oral health maintenance.

Mandibular Movement.—An ever-increasing amount of research is being directed toward establishing a better understanding of muscle actions and extending our knowledge concerning mandibular movements. One might well ask why this stress on muscle action and mandibular movement. The invention of the first articulator in 1805 started a long procession of modified instruments with one common function—that of reproducing mechanically the movements of the mandible. None have fully achieved this common goal.

It is not difficult, however, to rationalize failure to reproduce precisely the mandibular movements, the most complicated movements of any of the body units. Perhaps the best an articulator can be expected to do is to approximate mandibular movement and provide a guide to its inclinations and paths. Returning, then, to the question "Why should so much stress be placed on research in muscle action and mandibular movement?" it can be answered by saying that the more thoroughly we understand the physiologic, biologic, and neuromuscular aspects of the oral mechanism, the more readily we can adapt to and compensate for the recognized inadequacies of our instruments. It is thus that we increase our capability of constructing a satisfactory and functional prosthodontic appliance.

Because controversy persists over whether or not there is a true hinge movement of the mandible, much research has been centered on the temporomandibular joint. Apparently, there is general agreement that there is a hinge axis movement for at least a short distance prior to occlusal contact. If this is true, the hinge axis determination should be useful in establishing centric occlusion. Other records, however, become necessary for the establishment of proper tooth form and contour to accommodate harmonious mandibular movement laterally, protrusively, or retrusively, for then the hinge is no longer the predominant factor.

Through active research, the numerous forces concerned with mandibular action can be more clearly defined. Then we can adapt our thinking to fit the new findings and, recognizing the limitations of ourselves and our instruments, perhaps we can more nearly approach normal function.

Temporomandibular Joint.—The temporomandibular joint itself is probably the most sensitive reactor to occlusal disharmonies of the oral mechanism. It reflects defects in occlusal harmony in varying degrees, ranging from little or no effect other than an occasional click, through middle ear difficulties, to excruciatingly painful symptoms in the head and neck. Kelly and Goodfriend[2] reported that 70 per cent of patients with verified vertigo had occlusion-joint conditions as the cause, through a transfer of the occlusion-joint conditions to the vestibular system of the ear. Research of this sort enables us not only to define problems but to develop remedies and preventive measures.

Roentgenographic Studies.—Recent studies have shown, too, that as many as 25 per cent of edentulous patients have some form of positive roentgenographic findings, such as embedded root tips, impacted or unerupted teeth, and cysts, and that as high as 10 per cent have pathosis, such as radioluscent areas about root tips, residual cysts, sequestra, and malignancy. In view of the results of studies such as these, it is unthinkable that anyone would attempt the construction of a denture without first making a thorough examination of the patient.

Condition of Supporting Tissues.—Increasing attention is being given to the condition of the supporting structures and tissues—their health or, if injured, their restoration to health. Many abnormal conditions of the ridges, supporting structures, and tissues have been successfully treated through the simple procedure of providing rest. Vitamin therapy and exercise of the musculature are among the other means being studied for the treatment of abnormal ridges and tissues.

Impression Techniques.—Impression techniques continue to receive considerable attention. Each technique appears to have its advantages as well as its disadvantages. These are verifiable through study and research. Undoubtedly, the continuing search for a universal impression technique has engendered a tendency to adapt one technique to every patient. Certainly, the needs of the individual patient and the ability of the dentist will continue to be important factors in the selection, modification, and use of several techniques.

Retention of Dentures.—The mechanical retention of dentures has been a favored study area. The range extends from suction cups to the implantation of natural teeth. Currently, the implantation of magnets for retention is being developed and refined. The use of epoxy resins and allied substances for the implantation of natural teeth has created visions of tooth banks being evolved through which replacements for missing teeth might be made from previously collected and stored sterile natural teeth. Whether or not any of these approaches will be developed as effective and practical dental procedures will depend upon further research on tissue tolerance, retentive ability, and the capability of the replacements to withstand the forces of mastication.

Tooth Forms.—In the area of tooth form, opinions differ as to whether or not cuspless teeth should be employed and, if cusped teeth are to be used, what

height cusps are best. The answer probably lies in the judicious use of each within the indications of the individual case.

A recent report concluded that anatomic tooth forms cause more bone deformation over a larger area than nonanatomic tooth forms and that heavy bone structure is more resistant to deformation per unit force than average or light bone structure. On the other hand, another report concluded that patient preference is for 20 degree posterior teeth rather than for Hall's posterior teeth and that the latter produce more soreness during the adjustment period.

BACKGROUND KNOWLEDGE AND SKILLS

It is studies such as these (although the findings seem contradictory) that will lead to ultimate understanding of the basic problems and principles underlying satisfactory prosthodontic services.

The characterization and staining of teeth and denture-base materials comprise another continuing effort to more nearly satisfy the individual needs of patients. All in all, *it is increasingly clear that treatment with a prosthodontic appliance requires more than mechanical skills.* It requires a solid background of knowledge of the basic sciences—anatomy and pathology, histology and physiology, physics and chemistry, neurology and psychology. In addition, it requires a high order of skills in eliciting, understanding, and influencing the habits, attitudes, and values of each patient.

CHALLENGES

Although research is increasing our scientific and technical knowledge and competence in the area of prosthodontics, intelligent application of that knowledge appears to require of us a broader and deeper understanding of the biologic sciences than we have had before. If we believe this, it seems clear that the next decade will present great and exciting challenges.

First, the population increases projected for this country greatly exceed any scheduled plan for a similar increase in the number of dentists, so that the ratio of dentists to population will become less adequate within the next 10 years.

Second, the development and expansion of prepayment and postpayment plans for dental health services will be accelerated and will markedly increase the proportion of our population that can afford dental services.

Third, economic projections indicate that the population increases will be accompanied by an increased median income and will broaden the base of participation in available dental health services.

Fourth, the trend toward urbanization will continue and will increase the demand for dental services.

Fifth, increases in the level of education of future populations will greatly extend appreciation of and the demand for dental health services.

In other words, relatively fewer dentists and an increased demand for dental health services mean that all of us will be challenged by opportunities greater than ever before to make our services more efficient and to make them available to an increasing number of patients.

OPPORTUNITIES

If challenges in the next decade represent opportunities for leadership in solving emerging problems, those with competence in the area of prosthodontics will be especially favored. Much evidence supports this conclusion.

First, the 1957 National Health Survey reveals that there are 22 million edentulous persons in this country. This means that 1 out of every 8 persons is edentulous. This is an amazingly high figure. Nevertheless, it does not include the large number who have only one edentulous jaw or who are partially edentulous and in need of prosthodontic services.

Second, the population increases projected for the 1960s will add 5,000,000 more persons to the age group 65 and over, so that we will have a total of 20 million in this group.

Third, the 1960 amendments to the Social Security Act changed Title I from "Old Age Assistance" to "Grants to States for Old Age Assistance and Medical Assistance for the Aged" and provided that a subcategory of citizens 65 years of age and over, potentially numbering several million, may receive medical assistance, including dental services. The group to benefit is aged persons who are not eligible to receive old age assistance payments and who are considered to be unable to meet the cost of needed health services. Increased federal matching percentages of old age assistance funds is expected to make an additional $142,000,000 a year available to the states. Under this program, there is a ceiling on the per caipta expenditure which will be matched by the Federal government. However, there is no ceiling for amounts expended under medical assistance to the aged. Federal matching contributions under this new program will range from 50 to 80 per cent depending on the per capita income of the state, but the actual amount of money provided is limited only by the state allocation of funds for matching purposes.

Fourth, in 1959 bills which would authorize "denturists," or "denturologists," to make dentures directly for patients were introduced for legislative consideration and action in seven states—California, Georgia, Illinois, Michigan, Nevada, Oklahoma, and Washington.

In brief, these four items indicate that the actual and potential need for prosthodontic services is very large and is growing larger at an accelerated pace; that the health service requirements of the needy aged, including dental health services, will be provided through federal and state assistance programs; and that some dental technician groups are actively engaged in initiating action which would permit them to employ merchandising methods in exploiting those in need of prosthodontic services. Perhaps by paraphrasing a common complaint of welfare workers, the implications of these four items can be brought into better focus: "One of our most frustrating health service problems is our unsuccessful and fruitless efforts to secure dental health services, and particularly dentures for our welfare clients. Provisions are made for supplying all other kinds of health services, excepting dentures. Is there anything we can do about it?" Before considering our answer to this question, it may be worth noting that the needy aged and medically indigent, although a minority group, probably exert a greater influence on political

and legislative action and on the results of public referenda than do the great majority of prosthodontic patients who can and are willing to pay for health services.

LEADERSHIP

Now, what can you do to engage in the leadership opportunities reflected by these facts and trends? First, from the philosophic standpoint, the positive rather than the negative and defensive approach to the problem must be adopted. You must be actively identified with the conscience rather than with the fears of your community.

Second, you must be prepared to present your profession's values in situations where they are contested.

Third, if prosthodontic dental services are considered essential to physical and mental health, you must insist that they be made available to those who cannot afford to pay for them. If your community's health program for the needy does not include prosthodontic services, you should initiate organized constructive efforts to get them included, for in priority listings of essential dental services for the aged, dentures are second only to emergency relief of pain and infection.

Fourth, you must provide professional guidance to ensure that only qualified dentists are designated to supervise prosthodontic service programs and that provisions are made for continuing education of these dentists. You must also see to it that expert and consultative services are always available so that the services offered will be of high quality. In short, you must engage in those activities which will ensure that needy patients receive modern, effective prosthodontic health services. It is through such leadership activities that you will enhance the stature of your profession and maintain the respect of a grateful public. You will be engaging, indeed, in that humanistic quality of the Athenians, "The art of making gentle the life of mankind."

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CURRENT RESEARCH IN THE REGULATION OF FERTILITY

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IN PRESENTING A DISCUSSION of the problem of alarmingly rapid population expansion and the studies that are being made in the search for better methods of regulating fertility, it might appear that I am treading on ground ill-suited to the subject of prosthodontics. I hope, however, to show that the problem and its solution are so important that each of us, whatever may be his station in life, cannot avoid being affected by the problem and having an interest in its solution.

The major portion of this article will deal with some of the studies that are being made on the physiologic regulation of fertility. In this field I have a certain measure of competence. However, as an introduction to consideration of these studies, I shall outline the facts of the problem and thus attempt to show the importance of the solution. Here I am venturing into a subject in which I must lean heavily upon the analyses and projections of my demographic colleagues. In doing this, I shall endeavor to describe the basis, as I understand it, for the astounding growth that has occurred in the number of our species.

POPULATION GROWTH

In the process of his evolution, man has conquered his environment in a fashion and to a degree that should provoke pride in each of us. Each century has seen advances so that even in the less privileged countries man's lot has improved, and he now possesses advantages and comforts far beyond the dreams of his ancestors. Each century, along with its advances in knowledge and skills, saw an increase in man's numbers, but until 100 years ago, this increase was not spectacular. At the end of the Stone Age, the world's population was perhaps 10,000,000. When Christ was born, there were, as far as can be determined, about 200,000,000 people, and 1,600 years later, no more than 500,000,000. One hundred years ago, the population of the world was about 1,000,000,000; today, it is 3,000,000,000. If the present rate of increase (about 16 per cent each year) continues, the population will be more than 6,000,000,000 in the year 2000, and in the year 2060, it will be well above 18,000,000,000. The current rate of increase in world population leads to a doubling in 40 years (this, incidentally, is the rate of increase in our own country, where we may expect to have almost 400,000,000 people by the year 2000). In some countries, the rate of increase is such that 40 years will almost quadruple the population. Mexico, for example, has 36,000,000 people today. Their rate of increase, 3 per cent, if continued will result in a population of 123,000,000 in the year 2000. Some-

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where between the rate of our own country and that of Mexico are those of countries such as India and China, where the rate of increase is 2 per cent per year. India now has 400,000,000, China more than 650,000,000. By the year 2000 their populations, if the current rate of increase continues, will be 1,000,000,000 and more than 1,600,000,000, respectively.

I have cast somewhat astronomic figures rather long enough. You and I are scientists and, as such, are more particularly interested in why things happen and how they influence other things. As I have relayed the projections of the professional demographers, you may have been thinking, "What a field day the prosthodontists of the future will have with so many people." But at the same time, you must have wondered about what kind of a world that might be for all of us. Personally, I think we have it much better today.

Reason for the Population Explosion.—The reason for the population explosion is simple. The past 100 years has seen a progressive decline in the rate of deaths without a corresponding decrease in the birth rates. In the industrialized countries, death rates have declined slowly, but progressively, and have been accompanied by a corresponding, however slower, decrease in birth rates. Thus death rates now are less than 1 per cent in the industrialized countries and birth rates range between 1.5 and 2.6 per cent. The net result (births minus deaths) is an annual increase of about 0.5 per cent per year in countries such as Italy and Austria and 1.6 per cent in our own country.

As noted above, death rates have declined, but at a relatively slow pace in the industrialized countries. They did so as new developments in the control of disease were achieved and applied. It was only within the last few decades that most of these measures were made available to less privileged countries. Once applied, however, the achievements of modern science have been spectacular. Death rates of 3 per cent and more have been reduced to 1 per cent in less than a decade rather than over a century and more, as was the case for Europe and North America. However, in these countries, birth rates have remained high, and the inevitable consequence has been a burst of growth in numbers of people. Undoubtedly, given time, the high birth rates of Latin America, Asia (exclusive of Japan), and Africa will decline, but this will require a change in ingrained attitudes based on social, cultural, religious, and moral practices. These change slowly—particularly where habits of reproduction are concerned. It is easy to lower the death rate where effective measures are available. Since no one wishes to die, there is little or no opposition to governmental institution of measures for the eradication or control of disease. Birth rates are another matter, related as they are to sexual habits, which are in turn deeply rooted in attitudes not easily changed and which require education and motivation in the individual.

The Problem and Proposed Solutions.—Thus we are faced with a problem—that of balancing the number of people with the resources to support them. I shall not long dwell here upon the variety of suggestions that have been advanced by unrealistic optimists. These have included transporting excess populations to less densely populated areas or to other planets. Indonesia tried the former and found it to be completely impractical on the basis of both cost and resistance of the trans-

planted people. Interplanetary transportation of our present annual population increment (almost 50,000,000 people) would cost far more than the total gross annual product (value of goods and services) of the world.

It has been suggested, too, that a more equitable distribution of the world's goods would relieve the poverty of the less fortunate nations and lead eventually to stabilization of population growth. When the incomes of all the people of the earth are averaged, this gives each individual less than $400 per year (before taxes—and you can be sure even this paltry income would be taxed). This figure would almost certainly decrease, furthermore, since the people of industrialized areas would not be likely to sustain their productivity if they were not permitted to enjoy the goods they produced.

We are told, too, that man's capacity to develop technical skills of all sorts will provide for any increase in population. Technologic advances will be made and must be made, but they cannot hope to compete with the capacity to which man can increase his numbers. We shall learn how to use new forms of energy to take the place of our rapidly disappearing natural resources; synthetics will substitute for much of the materials we now employ in so many ways; we shall be able to demineralize sea water and thus help avert the crisis of water shortage that already besets many communities; land not presently arable will thus be put under cultivation; and we shall learn how to improve yields of crops by developing rapidly growing and disease resistant plants. These and presently less evident products of man's ingenuity are certain, but they will be achieved only at great cost, and, meanwhile, man's numbers will be increasing at least as rapidly as his ingenuity provides for them.

Availability of Food.—Meanwhile, and all of this is on that somewhat less rosy side of the situation, man will be eating many fewer choice meats, because he will be forced to the recognition that feeding animals is extravagantly wasteful of food. The caloric return of edible food given to animals is no more than 10 per cent. We shall not be able to waste the 90 per cent. Other food resources will be available through the extensive culture of marine life—particularly its plant life. How about a nice fillet of kelp or an appetizing fricassee of blue algae? As for me—I keep thinking about steaks and double lamb chops!

Of course, we shall not mind losing our open spaces and the wild life that we enjoy whenever we manage to get away from people. And none of us will ever miss our pet animals. But whether we like it or not, miss them we shall, because space and food will be too precious for such luxuries.

Capacity to Produce Food.—Recently, Dr. James Bonner of the California Institute of Technology estimated that the world might support a population of as much as 10,000,000,000 under a food program as efficient as that of Japan. Japan has achieved an efficiency of food production unequaled elsewhere, and there is grave doubt that most of the world will reach the efficiency of those tight little islands. Furthermore, the Japanese have not disregarded the importance of learning how to limit their rate of population increase. They have considered realistically the limited space of their islands, their rate of growth, and their potential for providing food and goods for their people. The result has been a logical program. Perhaps

some of their methods adopted in limiting population increase may not be acceptable universally, but the model set by Japan is one that the world in general must accept if it is to survive. It is really very simple in theory—increase production of goods and decrease production of people. We certainly shall do the former, but the latter comes a little harder.

REGULATION OF FERTILITY

At this point, I shall turn to a consideration of how we can regulate our fertility now and in the future. When mature judgment is employed, it is reasonable to believe that modern man, who has learned so much about the control of his environment, should unhesitatingly learn how to control his future life on this planet. That he has failed to accord proper attention to a most important aspect of this future is not surprising, since he has remained chained to ingrained habits and attitudes toward reproduction. Contributing to these have been the cultural, moral, social, and religious practices that govern much of man's behavior. In discussing these, particularly the religious aspect, as related to the need for attention to the control of population growth, the head of one of the recently emergent nations declared that he believed religions were made for men, not that men were made for religions, and that religious concepts must evolve to meet the needs of men. This is the kind of mature judgment that must spread below members of the top echelons who know, but will not always publicly recognize, facts in such sensitive areas as the regulation of fertility.

Methods of Controlling Fertility.—We have had at hand for many years a variety of effective means for the prevention of conception. These methods need only to be used properly and regularly to ensure against the occurrence of pregnancy. They include the diaphragm, condom, creams, foam tablets, coitus interruptus, and the "rhythm" method. The fact that these methods are closely associated with the coital act and thus demand too much calculation of the menstrual cycle or give rise to objections on economic, religious, and cultural grounds has led to disappointing results in their widespread adoption. Serious students of the problem have turned their hopes toward investigations in the field of education and motivation and toward physiologic methods for the regulation of fertility. I regard studies which will lead to better ways of teaching the importance of family limitation as extremely important—after all the perfect method for voluntary regulation of fertility would depend completely upon its faithful execution for perfect or even satisfactory results. However, I shall say no more about them here, but turn to a discussion of research in the physiologic approach to the regulation of fertility.

Biologically oriented scientists are recognizing that they have contributed materially to the increasing pressure of population growth and are turning toward studies on facts of reproductive physiology that may lead to better, cheaper, and, of course, safe methods of controlling fertility. They have the advantage of knowing about many points in the reproductive processes that are vulnerable to interference. These range from suppression of germ cell maturation, through inhibition of the transport of mature germ cells and of fertilization, to interference with early embryonic implantation and development.

Physiology of the Reproductive Process.—In the mammalian female, the reproductive process is a sequence of steps, each depending upon the successful fulfillment of the preceding ones. In brief, they can be outlined as follows: (1) production and release of the pituitary gonadotrophic hormones, (2) stimulation of egg and hormone production in the ovary by the gonadotrophins, (3) ovulation and passage of the egg into the oviduct, (4) fertilization, (5) cleavage and early development of the zygote during passage through the oviduct, (6) entrance of the zygote into the uterus and formation of the blastocyst, (7) implantation of the blastocyst in the endometrium, and (8) maintenance of embryonic development.

The male, too, has a sequential progression of the processes involved in reproduction. In outline, they are: (1) production and release of the pituitary gonadotrophic hormones, (2) production of spermatozoa and androgenic hormone by the testes under the influence of the gonadotrophic hormones, (3) transport of sperm into and through the epididymis and physiologic maturation of the spermatozoa, (4) passage of spermatozoa through the vas deferens to the ampulla, (5) suspension of sperm in the seminal plasma during ejaculation, (6) passage of sperm through cervix, (7) ascent of sperm through the uterus and oviducts and their capacitation, and (8) penetration of ovum by one spermatozoon.

In the case of both male and female, each step of the reproductive process is vulnerable to interference. Students of the subject are aware of this and are trying to learn enough about the mechanisms that are involved to devise methods for their regulation. I cannot begin to describe all of these studies in a brief discussion, but I shall endeavor to outline some of those which are either being carried out on human beings at the present time or which are likely to be done in the near future. In this process, I shall not attempt to follow the steps I have outlined for the two sexes, but simply describe particular studies. The order of description bears no relationship to the ultimate significance of the methods.

Inhibition of Ovulation.—It has been recognized for many years that the gonadal hormones, estrogens and androgens, would inhibit the secretion of the gonadotrophic hormones and, as a consequence, would interfere with ovulation. During the past 6 years, increased attention to the need for methods of regulating fertility has led to the examination of many new synthetic compounds to determine their effect on ovulation. Compounds which have a chemical relationship to the natural ovarian hormones have had special attention, and some of these proved to be effective even when administered orally. The two compounds which, at this time, have had enough study to merit mention are 17α-ethynyl-17β-hydroxy-5(10)-estren-3-one (norethynodrel)* and 17α-ethinyl-19-nortestosterone (norethisterone).† These compounds are available for clinical use as progestins; the former is now licensed for use as an oral contraceptive, and the latter will be, although under a different trade name.

Before clinical trials were undertaken with these compounds, extensive animal experiments gave assurance of their effectiveness as ovulation inhibitors. When use in women was instituted, few students of reproductive physiology doubted the

*Enovid.
†Norlutin.

effectiveness of the drugs. At the present time, projects are underway, in this country and elsewhere, involving at least 4,000 women. We have no way, at the moment, of estimating how many women, not in organized projects, are using them as their sole contraceptive agent. In the organized projects, the results have been spectacular and show conclusively that the method is extremely effective. There is some variation, of course, in the occurrence of pregnancy in the different projects, but the average for all is less than two per 100 years of exposure. This means an effectiveness of 98 per cent and includes pregnancies that occurred in women who failed to use the method as prescribed. It is almost certain that the conceptions that did occur were the result of failure of the women to take the pills regularly.

The use of norethisterone or norethynodrel as a contraceptive has involved ingestion of one 10 mg. pill each day from the fifth to the twenty-fifth day of the menstrual cycle. Cessation of treatment is followed by menstruation within a few days. This schedule is repeated each cycle. In the case of norethynodrel, which for reasons I shall not consider here has thus far been studied more extensively than norethisterone, 5 mg. pills have been shown to be equally effective in inhibiting ovulation.

Inhibition of ovulation results from the suppression of the gonadotrophic hormones. The compounds have the capacity to do this and thereby to abolish the normal menstrual cycle. By way of their progestin-like and estrinlike activities, they are able to make provision for an artificial cycle which, interestingly enough, is usually more regular than the spontaneous cycles of the average woman had been. Other effects of these drugs may also contribute to their effectiveness as contraceptive agents. They may so hasten endometrial maturation that any egg which does escape from the ovary and is fertilized cannot implant in the uterus because the endometrium has advanced beyond the stage that is optimal for reception of an embryo. Furthermore, drugs which have the kind of activity that is present in norethisterone and norethynodrel can change the characteristics of cervical mucus so that spermatozoa are unable to effect passage to the uterus.

Whatever the mechanism of effectiveness may be, the evidence indicates that these compounds are excellent physiologic contraceptives when used as prescribed. The evidence indicates, too, that they can be used safely for at least 4 years without damaging the capacity of the female to conceive promptly after treatment is halted. There is, of course, no assurance as yet that continued use of the drugs for many years can be carried out with complete safety. Further study must be made before we have such facts at hand, but every evidence from laboratory investigations indicates that there is little reason to fear serious side effects. Some women do experience minor disturbances, such as headache, nausea, and "breakthrough bleeding," but these instances are relatively infrequent and usually persist for a short time only.

There is some concern about the cost of the drugs. As yet, a dose level of even 2.5 mg. per day for 20 days would make their general use prohibitive by people in underprivileged countries. However, there is reason to believe that the cost may be reduced and, also, that less expensive new compounds will be made available.

Inhibition of Spermatogenesis.—Many compounds, including norethynodrel and norethisterone, have the capacity to inhibit the production of male germ cells by suppressing secretion of gonadotrophins. We have studied this by examining testicular biopsies and seminal specimens, before, during, and after administration of the drugs. The effectiveness of such agents is clearly evident, but they have the unwelcomed additional action of suppressing the secretion of male sex hormone. This effect lowers libido and potentia and, as a consequence, would make their acceptance difficult.

Although the steroidal compounds, such as these compounds, are not likely to be widely accepted by human males because they lower production of male sex hormone, other kinds of compounds may have application. At the present time, we are studying several kinds of drugs which inhibit the production of spermatozoa without reducing the secretion of androgenic hormone. These drugs have a wide variety of chemical composition, for example, some are bacteriostatic (nitrofurazones and thiophenes) and others are amebicidal (dichloroacetamides). Studies in my laboratory have shown that these and other drugs are effective in suppressing spermatogenesis. The dichloroacetamide compounds seem to have the best chance for use in men.

Other methods of inhibiting spermatogenesis are being explored. One of these is the application of heat. It has been recognized for many years that the scrotal position of the testes in most mammals is important to normal production of male germ cells and that elevation of temperature by no more than a few degrees has deleterious effects on their formation. Recent studies we have made in collaboration with Dr. Tokuyama of Japan and Dr. Steinberger of Detroit have shown that it is possible by periodic application of heat to reduce sperm production to levels incompatible with fertility.

Inhibition of Gonadotrophin Action on the Gonads.—This method of suppressing gonadal activity in both sexes depends upon the prevention of their response to the gonadotrophic hormones. Two kinds of approaches have been studied and may find application in man.

Extracts of plants of the genus Lithospermum, when fed to laboratory animals, suppress fertility. Although the evidence at hand is incomplete, it is possible that some plants do contain agents which inhibit fertility. In the case of Lithospermum, it has been claimed that the *modus operandi* is through inhibition of gonadotrophic action on the gonads.

A second method of inhibiting the action of gonadotrophins is based on the production of antigonadotrophic substances in response to the injection of gonadotrophins from a foreign species. This possibility remains an area for further study, but we have sufficient information to know that gonadal function in man can be inhibited by the administration of pituitary extracts from nonhuman sources.

Immunologic Mechanisms in Reproduction.—The formation of antigonadotrophic substances actually falls in this category. Other types of immunologic procedures appear to be even more promising as possible regulators of fertility.

Numerous studies have shown that agglutinating substances are concerned in the fusion of sperm and egg. When these substances (called fertilizin and anti-

fertilizin) are present on the surface of the respective gametes, fertilization is facilitated. However, if they are also present in the solution containing the germ cells, fertilization is hindered. If it is firmly established that gametes of the human produce interacting substances of this nature, it would be feasible to attempt controlled interference with this biochemical mechanism in the fertilization process. The evidence indicates that mammalian spermatozoa are prevented from agglutinating and, therefore, from losing their fertilizing capacity because of the presence of a protein substance present in the semen. And it has been demonstrated that antibodies can be formed which precipitate with antagglutinins. Another immunologic approach involves the formation of antibodies against the germ cells themselves; until now most work has been with the male gametes, and Freund and his collaborators have been able to induce the loss of all germinal tissue from the testes of guinea pigs immunized with homologous testicular extracts. This has been confirmed by others who have also found that extracts of guinea pig testis also induce sterility when used to immunize female guinea pigs. The mechanism of this latter phenomenon is not yet fully understood. One of the possibilities which has been suggested is that the immunized female is "protected" against spermatozoa, so adequate quantities of antibodies appear in the female reproductive tract and inactivate spermatozoa deposited during coitus.

Another line of work that combines known endocrine principles and immunology is the attempt to inhibit hormones of the reproductive system immunochemically. The most advanced work is that of Lieberman and his colleagues, who have been attempting to form antibodies to protein-steroid complexes. These results to date indicate that the antibodies to the protein hapten of the complex will reduce the hormonal activity of the protein-steroid complex when antigen-antibody combination occurs. When the form of the naturally circulating steroids in the blood is more fully understood, this type of work could provide dramatic results.

Interference With Early Embryonic Development.—Evidence at hand suggests that the embryo may be destroyed by certain drugs prior to implantation.

One compound showing this effect, and which we have studied, is 1-(*p*-2-diethylaminoethoxyphenyl)-1-phenyl-2-*p*-anisylethanol, more commonly known as ethamoxytriphetol or MER-25. We have found that if this compound is given to rats during the first 4 days after fertilization of the egg, conception is prevented. If given later, no effect occurs, pregnancy progressing normally. Studies subsequently made in vitro on fertilized eggs of rats, rabbits, and sea urchins showed that the drug apparently acts directly on the young zygote rather than by altering some physiologic mechanism.

A second compound that we have been studying is 1-(*p*-β-diethylaminoethoxyphenyl)-1,2-diphenyl-2-chloroethylene, more easily designated as chloramiphene or MRL-41. As yet, not as much is known about it as is the case with MER-25, but it appears to have the same antizygotic effect and to be considerably more potent. If these substances have the same effect in man as in laboratory animals, we shall have oral contraceptives which in many respects are more desirable than the steroids.

Another substance, dimethylhydroquinone, has been studied in India and reported as having an anti-implantation effect. In the case of this compound, the action is supposed to be through interference with the action of progesterone on the endometrium, thus preventing the embryo from implanting. Clinical trials in India indicate that the compound taken orally twice during the week after ovulation reduces the conception rate by 50 per cent. More studies are needed, particularly in view of the fact that animal trials have not shown a material effect on fertility.

Interference With Embryonic Development After Nidation.—A variety of compounds have been shown to have the capacity to destroy the embryo after it has established itself in the uterus. This result seems to be achieved by competitive effects on essential nutritional factors. Such compounds include aminopterin, diazo-acetyl-serine, and diazo-oxo-norleucine. In most societies, this method of fertility control would be rejected, but in cases where interruption of pregnancy has legal status, compounds which destroy the embryo would be acceptable. It would be important, however, that the drugs have a wide margin of safety for the female. Those that have been studied are compounds produced for treatment of leukemia and as such have effects on the bone marrow. They also may cause abnormalities of development if used improperly or ineffectively.

Other Methods.—There are many additional studies on the physiology of reproduction that are being made and which will contribute to the program of devising new, safe, cheap, and acceptable methods of regulating fertility. These include studies on sperm production, sperm maturation in the epididymis and oviduct, fertilization mechanisms, and the chemical and physical properties of cervical, uterine, and oviductal secretions. The details of these investigations will not be attempted here.

Two methods less obviously physiologic, but potentially very important, should be given brief attention. One of these is interference with sperm or egg passage by ligation of the vas deferens or oviduct. These procedures are safe and effective methods of controlling fertility and are receiving increasing acceptance in many countries. Vasectomy or salpingectomy, as the case may be, establishes permanent infertility and as such is to be used after the desired number of children are achieved. However, studies also are being made to improve the methods for re-establishing patency of the ducts in both sexes. When this objective is attained, the method is likely to have even wider acceptance.

A second procedure being studied is the use of intrauterine devices. This is not a new idea by any means, but interest in it has been revived by the availability of new plastic materials which are nonirritating to tissue. Several projects are now underway to assess the contraceptive effectiveness, safety, and mode of action of small, removable devices placed within the uterine cavity.

Finally, I should like to mention studies that are being made to improve the efficiency of the "rhythm" method. As is generally known, this is a procedure whereby the time of probable ovulation is calculated by observing the variation in the length of a number of menstrual periods. Coitus is avoided during the days on which ovulation is likely to occur and for several days on either side of that time. The procedure can be highly effective, but so is complete abstinence—and such is

virtually necessary in women who have very irregular cycles. For them to practice the method, the time that must be allowed for ovulation alone may be as much as 2 weeks. There is hope that it will be possible to learn how to predict ovulation accurately enough to permit limiting the period of abstinence to a few days. This would increase the efficiency of the method and tend to make it acceptable to more people.

SUMMARY AND CONCLUSIONS

I have attempted to portray what is happening in our world as far as the increase in numbers of people is concerned and how this is likely to affect us and our descendants, whether we be bricklayers, farmers, physiologists, or prosthodontists. Since it seems to be of vital importance that we learn how to regulate that increase by methods other than those that have been available, students of reproductive physiology have recently turned their attention to investigations that are designed to develop methods of regulating fertility by physiologic procedures. I have described some of these studies and in so doing have tried to provide samples of those which are now being applied in man as well as those which are in the area of developmental research. Progress is encouraging, but far from equal to the need of the problem. The challenge that faces us is so important that more imaginative studies are needed. More research funds are needed, of course, but more urgent are new ideas. To that end we strive to attract and train people with new skills and new viewpoints. Through the application of the same ingenuity man has shown in solving so many difficulties, it will be possible, we feel certain, to meet and resolve the problems of man's numbers in relation to the resources requisite for his support.

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DENTIST–DENTAL LABORATORY HARMONY

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MOST DENTISTS utilize services of a commercial dental laboratory. Only a select few who specialize in prosthetic dentistry employ a qualified dental laboratory technician in the office; these dentists have a distinct advantage.

ADVANTAGES OF PRIVATE TECHNICIAN

Many advantages are gained from the private dental laboratory technician: (1) there can be close personal communication, (2) there is more familiarity with the techniques used by the dentist and there are fewer mistakes, (3) the dentist and other auxiliary personnel can be relieved of laboratory procedures, (4) techniques need not be limited to those which can be delayed or restorations that can be transported, (5) appointments can be made efficiently because time estimates can be judged correctly, (6) the dentist can maintain a constant supervisory position and at the same time more readily accept helpful suggestions from the technician, and (7) additional adjunctive personnel used correctly makes the dental office more efficient.

The average practitioner of general dentistry finds this employee economically impractical. Therefore, the afore-mentioned advantages are absent unless a strict routine procedure is followed in coordinating the work of the dentist and the commercial dental laboratory.

PROBLEMS IN USE OF COMMERCIAL LABORATORY

The employment of the commercial dental laboratory poses many problems. Mutual satisfaction is obligatory. The commercial laboratory in many instances is not given sufficient help from the dentist to achieve this necessary harmony.

The dentist, by placing untoward demands on the laboratory, creates ill will between two people who must work together. Disharmony between dentists and laboratories and slipshod dentistry are responsible for one of our current problems—the laboratories that practice dentistry illegally.

Maximum cooperation between the dentist and the commercial dental laboratory increases the efficiency of both. This increased efficiency results in happiness for both parties.

RECOMMENDATIONS FOR DENTIST–DENTAL LABORATORY HARMONY

The following recommendations would encourage harmony between the dentist and the commercial dental laboratory:

1. Dental materials must be used as specified. Alginate (irreversible hydrocolloid) and other impressions made from elastic materials must be poured immediately to reduce distortion.

2. Both the dentist and the commercial dental laboratory must use techniques that are predictable.

3. The commercial dental laboratory must be given adequate time so that the service can be properly accomplished.

4. Untoward economic demands must not be placed on the commercial dental laboratory.

5. A respectable business relationship must be maintained between the dentist and the commercial dental laboratory.

6. The dentist must design his own dentures and other restorations so the responsibility for failures resulting from design will be with the dentist, where it belongs.

7. Each procedure that is transferred from the dental office to the commercial dental laboratory must be accompanied by a written instruction sheet that gives explicit and sufficient directions.

If these suggestions are followed, the relationship between the dentist and the commercial dental laboratory will be greatly improved and both will be more efficient. The dentist, by cooperating and being cooperated with more readily, will be able to alleviate greatly the problem of illegal practitioners by making the position of the skilled and respectable dental laboratory technician more secure.

Medical Arts Bldg.
207 Elm St.
Holyoke, Mass.

NEWS AND NOTES

MEETINGS

Western Society of Periodontology, Tropicana Hotel, Las Vegas, Nev., March 19 to 21, 1961. For further information write to Dr. Daniel Feder, 152 South Lasky Dr., Beverly Hills, Calif.

International Association for Dental Research, Hotel Statler, Boston, Mass., March 23 to 26, 1961. For further information write to Howard F. Campbell, 2000 P St., N.W., Washington 6, D. C.

Twelfth Mid-Atlantic States Conference on Dentistry, Buck Hill Falls, Pa., April 16 to 21, 1961. For further information write to Director, University of Pennsylvania, School of Dentistry, 4001 Spruce St., Philadelphia 4, Pa.

Spanish Society of Orthodontics, Valencia, April 27 to 30, 1961. For further information write to A. J. Cervera, Avenida del Oeste 29, Valencia, Spain.

American Association for Cleft Palate Rehabilitation, Montreal, Que., May 4 to 6, 1961.

Academy of Denture Prosthetics, Radisson Hotel, Minneapolis, Minn., May 7 to 12, 1961.

Southeastern Academy of Prosthodontics, Americana Hotel, Miami Beach, Fla., May 18 to 21, 1961.

Twelfth Annual Berkshire Conference in Periodontology and Oral Pathology, Eastover Hotel, Lenox, Mass., June 18 to 22, 1961.

Bicentennial of the Death of Pierre Fauchard, Paris, July 1 and 2, 1961. For further information write to M. Max Filderman, Secrétaire Général du Comité National du Bicentenaire de Fauchard, 67, Rue de Tocqueville, Paris XVIIe, France.

Australian Dental Association, 16th Australian Dental Congress, Sydney, New South Wales, Aug. 14 to 18, 1961.

Pacific Coast Society of Prosthodontists, Empress Hotel, Victoria, B. C., Aug. 31 to Sept. 2, 1961.

American Academy of Maxillofacial Prosthetics, Benjamin Franklin Hotel, Philadelphia, Pa., Oct. 11 to 13, 1961.

ANNOUNCEMENTS

Reprints of the second edition of the *Glossary of Prosthodontic Terms* are now available. Prices: 1 to 20 copies, fifty cents each; 20 to 49 copies, forty cents each; 50 to 99 copies, thirty-five cents each; 100 or more copies, twenty-five cents each. Orders for less than 100 will be mailed prepaid; orders for 100 or more will be sent shipping charges collect. Cash, check, money order, or institution purchase order *must* accompany the order for reprints. Orders will not be filled otherwise. Address: Glossary Reprints, 3939 Old Brownsboro Road, Louisville 7, Ky.

Reprints of Reports Nos. 1 and 2, "Principles, Concepts, and Practices in Prosthodontics," may be obtained by writing Dr. W. Les Warburton, Secretary-Treasurer, Academy of Denture Prosthetics, 807 Medical Arts Bldg., Salt Lake City 11, Utah. The price is 25 cents for both, with a 20 per cent discount allowed on purchases of 20 or more. Cash, check, or purchase order *must* accompany the order.

The 17th Annual Post-College Assembly of the College of Dentistry, The Ohio State University, will be held April 19 and 20, 1961.

For further information write to Dr. Steve Kolas, The Ohio State University, College of Dentistry, 305 West Twelfth Ave., Columbus 10, Ohio.

The Tenth Annual Meeting of the American Academy of Maxillofacial Prosthetics will be held Oct. 11 to 13, 1961, at the Benjamin Franklin Hotel in Philadelphia, Pa.

For further information write to Dr. Mervin C. Cleaver, Executive Secretary, 2330 Linwood Ave., Apt. 3H, Coytesville, Ft. Lee, N. J.

FELLOWSHIPS

Four teaching fellowships paying a stipend of $3,600 to $5,000 will be available from the Fund for Dental Education during 1961 to persons wishing to prepare themselves for careers in dental education, Maynard K. Hine, president of the Fund, has announced.

Application for these fellowships may be made during the first quarter of 1961, January through March, on forms secured through the dental school deans or directly from the Fund office at 840 North Lake Shore Dr., Chicago 11, Ill.

With the addition of two fellowships recently established, the following awards are available to dentists or dental seniors planning to enter dental teaching: the American Dental Association Teaching Fellowship of $5,000 which is sponsored by The Great-West Life Assurance Company; the American Dental Trade Association Teaching Fellowship of $3,600; and two Fund for Dental Education Teaching Fellowships of $3,600 each.

Applicants must be graduates of dental schools in the United States or Canada and must be prepared to submit academic records showing they are qualified to enroll in graduate dental education programs. Applicants are required to sign a statement indicating they expect to become dental teachers upon completion of the fellowship training.

Loyola University, Chicago College of Dental Surgery, is offering a research and teacher training program in oral biology. This is under a teacher training grant from the National Institutes of Health. It is designed for candidates who desire a teacher's career in basic sciences or in clinical subjects. The stipends are up to $5,000 per year, and the program can lead to an advanced degree.

For further information and application write to Dr. Harry Sicher, Director, Loyola University, Chicago College of Dental Surgery, 1757 West Harrison St., Chicago 12, Ill.

Tufts University, School of Dental Medicine, announces two research fellowships in periodontology beginning September, 1961, and three full-time graduate courses in periodontology.

For further information and application write to Dr. Irving Glickman, Periodontology, Tufts University, School of Dental Medicine, 136 Harrison Ave., Boston 11, Mass.

POSTGRADUATE COURSES

The University of Alabama, School of Dentistry, announces the following refresher courses:

Pedodontics for the General Practitioner: Dr. Sidney B. Finn, May 6 and 7, 1961.

Root Canal Therapy Followed by Apicoectomy: Dr. Adeeb E. Thomas, May 10 to 12, 1961.

Surgical Anatomy of the Head and Neck: Dr. Harry Sicher, May 22 to 24, 1961.

For further information and application write to the Director, Refresher Course Program, University of Alabama, School of Dentistry, 1919 Seventh Ave., South, Birmingham, Ala.

Boston University, School of Medicine, Division of Graduate Studies, Department of Stomatology, announces the following postgraduate courses:

Seminar—Review of Occlusal Concepts in Restorative Dentistry: Dr. Morton Amsterdam, Dr. Ernest R. Granger, and Dr. Edward J. Hoffman, March 17 and 18, 1961.

The Abutment Tooth: Staff of the Department of Stomatology, March 24 and 25, 1961.

The Use of Ultrasonics in Periodontal Therapy: Dr. Henry M. Goldman, April 1, 1961.

Apicoectomy-Surgical Endodontic Procedures: Dr. Herbert Schilder, April 10 to 14, 1961.

Periodontal Therapy: Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, Dr. William Pendergast, Dr. Jack Bloom, and associates, April 24 to 29, 1961.

Advanced Course in Periodontal Therapy: Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, Dr. William Pendergast, and associates, April 24 to 29, 1961.

Practice Management and Audio Analgesia: Dr. Frederick A. Trevor, April 28 and 29, 1961.

Head and Facial Pain of Dental and Non-dental Origin: Dr. Charles A. Kane and Dr. Kurt H. Thoma, May 13, 1961.

Full Mouth Reconstruction: Dr. Leo Talkov, Dr. David J. Baraban, Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, and Dr. J. David Kohn, May 15 to 19, 1961.

Pedodontics for the General Practitioner: Dr. Harold Berk, May 19 and 20, 1961.

Surgical Procedures in Periodontal Therapy: Dr. Lewis Fox and associates, May 22 to 26, 1961.

For further information write to Director of Postgraduate Studies, Department of Stomatology, Massachusetts Memorial Hospitals, 750 Harrison Ave., Boston 18, Mass.

The Albert Einstein College of Medicine, Department of Dentistry, will sponsor postgraduate courses in the following subjects during the spring of 1961:

Anesthesiology, Endodontia, Oral Pathology, Oral Surgery, Periodontia, and Prosthetics.

These courses are designed to be integrated into the general dental practice. Lecture sessions will be held at the Albert Einstein College of Medicine and the clinical demonstrations at the Dental Clinic, Jacobi Hospital.

For further information and application write to the Director, Postgraduate Dental Division, Albert Einstein College of Medicine, Eastchester Rd. and Morris Park Ave., Bronx 61, N. Y.

New York University, College of Dentistry, announces the following postgraduate course:

Partial Dentures, April 19 to 21, 1961.

For further information and application write to Director, Postgraduate Division, New York University, College of Dentistry, 421 First Ave., New York 10, N.Y.

Northwestern University Dental School announces the following postgraduate courses:
Basic Oral Surgery, March 20 to 24, 1961.
Major Oral Surgery—A1, March 20 to 24, 1961.
Major Oral Surgery—A2, March 27 to 31, 1961.
Complete Denture Procedures, March 27 to 30, 1961.
A Practical Approach to the Use of Gold Foil, April 10 and 11, 1961.
Prosthetic and Orthodontic Rehabilitation for the Cleft Palate Patient, April 10 and 11, 1961.
Major Oral Surgery—B, April 10 to 14, 1961.
Oral Diagnosis, April 26 and 27, 1961.
Edmund Noyes Memorial Lecture, May 3, 1961.
The Use of Drugs in Dental Practice, May 8 to 10, 1961.
Recent Advances in Amalgam Techniques, May 15 and 16, 1961.
Conference for Teachers of Pedodontics, June 5 and 6, 1961.
For further information and application write to Northwestern University Dental School, 311 East Chicago Ave., Chicago 11, Ill.

The Ohio State University, College of Dentistry, announces the following postgraduate courses:
Complete Denture Prosthodontics: Dr. Carl O. Boucher, April 3 to 7, 1961.
Hypnosis in Dentistry: Dr. Charles Pfersick, April 10 to 12, 1961.
Periodontics: Dr. John Wilson and Dr. William Walton, April 13 to 15, 1961.
Removable Partial Denture Prosthodontics: Dr. Victor Steffel, April 24 to 28, 1961.
General Anesthesia: Dr. Morgan Allison, May 15 to 19, 1961.
Dental Drugs in Action: Dr. W. Russell Kampfer, May 19 and 20, 1961.
Oral Surgery: Dr. Morgan Allison, May 22 to 26, 1961.
For further information and application write to The Ohio State University, College of Dentistry, 305 West Twelfth Ave., Columbus 10, Ohio.

The University of Pennsylvania, School of Dentistry, announces the following postgraduate courses:
Complete Denture Prosthesis, March 27 to 30, 1961.
Endodontics, April 10 to 21, 1961.
Minor Tooth Movement and Temporary Stabilization, April 12 to 14, 1961.
Twelfth Mid-Atlantic States Conference on Dentistry, April 16 to 21, 1961.
For further information and application write to Director of Postgraduate Courses, University of Pennsylvania, School of Dentistry, 4001 Spruce St., Philadelphia 4, Pa.

The University of Pittsburgh, School of Dentistry, and the Odontological Society of Western Pennsylvania announce the following postgraduate courses:
Periodontal Therapy: Dr. D. Walter Cohen, assisted by Dr. Herbert E. Meyers, April 12 to 14, 1961.
Periodontal Therapy (Clinical Demonstration): Dr. D. Walter Cohen, assisted by Dr. Herbert E. Meyers, April 15, 1961.
For further information and application write to Dr. H. W. Zwicker, 547 North Ave., Millvale, Pittsburgh 9, Pa.

Tufts University School of Dental Medicine announces the following postgraduate courses:
Endodontics for the General Practitioner, March 20 to 23, 1961.
Partial Denture Design and Construction, March 23 and 24, 1961.
Newer Concepts for Inlay Construction, April 4 and 5, 1961.

A Special Participation Course in Periodontology, April 24 to 28, 1961.

Clinical Adjustment of the Occlusion, May 3 to 5, 1961.

Special Course in Surgical Management of Skeletal Deformities, May 8 to 10, 1961.

The Diagnosis and Treatment of Pain and Other Symptoms Arising From Temporomandibular Joint Disturbances, May 23 and 24, 1961.

Full Denture Prosthesis, June 5 to 9, 1961.

For further information and application write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

The Medical College of Virginia announces the following postgraduate courses:

Complete Denture Prosthesis: Dr. M. M. DeVan, March 20 to 24, 1961.

Clinical Photography: Dr. P. J. Modjeski and Mr. Melvin C. Shaffer, April 10, 1961.

For further information and application write to Dr. H. T. Knighton, Director of Postgraduate Instruction, School of Dentistry, Medical College of Virginia, Richmond, Va.

HOSPITAL INTERNSHIP AND RESIDENCY PROGRAMS

The Veterans Administration Hospital, Iowa City, in affiliation with the State University of Iowa, College of Dentistry, announces that two rotating dental internships and one residency in prosthetics will be available for 1 year beginning July 1, 1961.

For further information and application write to the Chief, Dental Service, Veterans Administration Hospital, Iowa City, Iowa.

The Veterans Administration Hospital, Philadelphia, is now accepting applications for the 1 year rotating internships available July 1, 1961. The program is given in cooperation with the affiliated Dental and Medical Schools. A Certificate of Internship is awarded by the Hospital.

For further information and application write to Dr. S. L. Orlean, Chief, Dental Service, Veterans Administration Hospital, Philadelphia 4, Pa.

The Veterans Administration Medical Teaching Group Hospital of Memphis announces that two rotating dental internships and one residency in prosthodontics will be available for the year beginning July, 1961.

For further information write to Dr. Robert T. Holt, Chief of the Dental Service, Veterans Administration Medical Teaching Group Hospital, Memphis 15, Tenn.

Those interested in a 2 year residency program in prosthodontics at the Veterans Administration Center, Wood, Wis., beginning July 1, 1961, should apply immediately. The residency program is affiliated with Marquette University, School of Dentistry.

For further information and application write to the Manager, Wood Veterans Administration Center, Milwaukee, Wis.

The Dental and Oral Surgery Service of The Mount Sinai Hospital in New York City announces that it is accepting applications for internships and residency for the calendar year beginning July, 1961.

For further information and application write to Dr. Max Fuchs, Assistant Director, The Mount Sinai Hospital, 11 East 100th St., New York 29, N. Y.

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